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AMERICAN CONCRETE INSTITUTE

VOL. II MARCH, 1914 No. 2

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PURPOSE OF THE INSTITUTE.

It is the purpose of the Institute, by means of conventions and publications, to increase and disseminate knowledge in regard to the use of cement, concrete and allied products; to conduct research into their properties and uses; and to formulate recommended practice and standard specifications.

Its objects are purely educational.

JOURNAL
OF
AMERICAN CONCRETE INSTITUTE

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NATIONAL ASSOCIATION OF CEMENT USERS
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The Institute is not responsible, as a body, for statements and opinions advanced in its publications

VOL. II. MARCH, 1914 NO. 2

DISCUSSION IN JOURNAL.

It will hereafter be the policy of the Institute to publish in the current issues of the Journal, not only the reports, papers and communications that are to be presented or that have been presented at the Annual Convention, but also original communications from its members.

The columns of the Journal are open for the discussion of any matter published in it, and it is hoped that the members will avail themselves of this opportunity, to the end that the discussions at the Annual Convention may be supplemented by the discussions of those who were unable to attend. It is believed that much useful information will thus be obtained which will be of direct benefit to all members of the Institute as well as to its various Committees in the formulation of the Standards and of the Recommended Practice.

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Institute Notes.

Standards Adopted by the Institute.

1 Standard Specifications for Cement with Appendix on Standard Methods of Testing and Chemical Analysis, 23 pp.

2. Standard Specifications for Portland Cement Sidewalks, 6 pp.

4. Standard Building Regulations for the Use of Reinforced Concrete, 13 pp.

5. Standard Specifications for One Course Concrete Highway, 10 pp.

6. Standard Specifications for Portland Cement Curb and Gutter, 7 pp.

7. Standard Recommended Practice for the Use of Reinforced Concrete, 21 pp.

8. Standard Specifications for Scrubbed Concrete Surfaces, 3 pp.

9. Standard Recommended Practice for Concrete Drain Tile, 3 pp.

10. Standard Recommended Practice for Concrete Architectural Stone, Building Block and Brick, 4 pp.

11. Standard Specifications for Concrete Architectural Stone, Building Block and Brick, 3 pp.

12. Standard Building Regulations for the Use of Concrete Architectural Stone, Building Block and Brick, 3 pp.

13. Standard Specifications for Plain Concrete Floors, 6 pp.

14. Standard Specifications for Reinforced Concrete Floors, 5 pp.

15. Standard Specifications for Portland Cement Stucco on Metal Lath, Brick, Tile or Concrete Block, 9 pp.

16. Standard Methods for the Measurement of Concrete Work, 7 pp.

17. Standard Specifications for One Course Concrete Street Pavement, 10 pp.

18. Standard Specifications for Two Course Concrete Street Pavement, 11 pp.

The above Standards can be obtained at the price of 25 cents each or in lots of ten or more at 20 cents each. Special price to Members 15 cents each or 10 cents each in lots of ten.

Reduced Price for Back Volumes.

Members of the Institute can obtain copies of back publications at the following special prices:

Vol. I, 50 cents; Vols. II to VI, $1.50 each; all in paper binding. For cloth or half morocco binding there is an additional charge per volume of 50 cents or $1.00 respectively. Vol. VII is available only in cloth binding, $2.00, or half morocco, $2.50.

Membership Certificate.

A Certificate of Membership in this Institute will be furnished to any member in good standing, i. e., whose dues are paid up to date. These Certificates are printed from an engraved steel plate. The name of the member is engrossed and the Certificate will be signed by the President and Secretary. The Certificates are about 10 x 14 ins., and have sufficient margin to be framed 14 x 17 ins. They are engraved on parchment or parchment paper, both suitable for rolling or framing.

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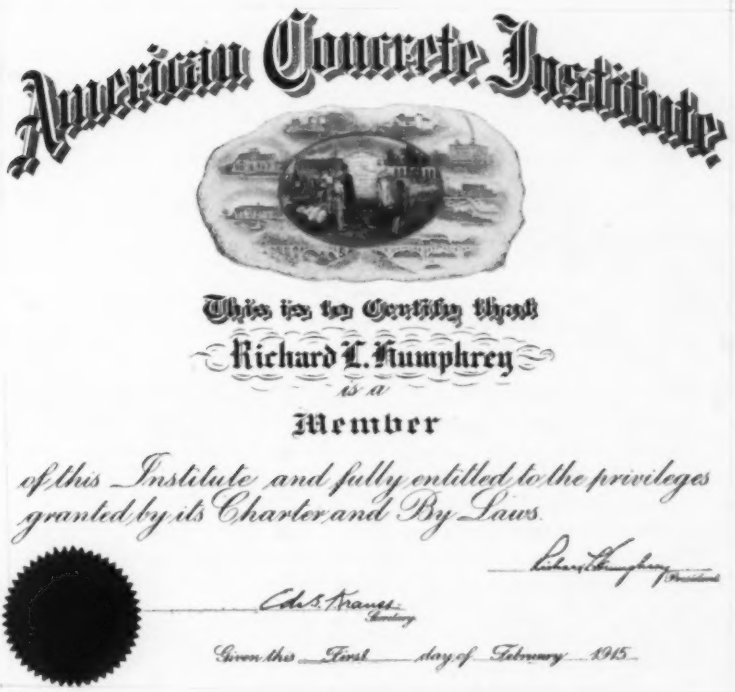
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Richard L. Humphrey
is a
Member
of this Institute and fully entitled to the privileges granted by its Charter and By Laws.
Edw. S. Frances
Given this First day of February 1915

MEMBERSHIP CERTIFICATE.

Synopses of Recent Articles on Concrete.

Reviewed February 1 to 28, 1914.

The synopses given below are for the purpose of keeping the members of the Institute in touch with the leading articles of interest appearing in the many technical journals and are not complete reviews of these journals. The publications regularly reviewed appear below and the number given corresponds to the number following the title of the paper. The length of the article in pages, whether illustrated or not, is noted, and the publications reviewed in which it appears:

1. Canadian Engineer, Toronto, Ontario, Canada.
2. Cement, New York, N. Y.
3. Cement and Engineering News, Chicago, Ill.
4. Cement Era, Chicago, Ill.
5. Cement World, Chicago, Ill.
6. Concrete Age, Atlanta, Ga.
7. Concrete Era, Los Angeles, Cal.
8. Concrete-Cement Age, Detroit, Mich.
9. Concrete and Constructional Engineering, London, England.
10. Engineering and Contracting, Chicago, Ill.
11. Engineering News, New York, N. Y.
12. Engineering Record, New York, N. Y.
13. Good Roads Magazine, New York, N. Y.
14. Portland Cement, Kansas City, Mo.
15. Rock Products, Chicago, Ill.
16. Proceedings American Railway Engineering Association, Chicago, Ill.
17. Western Contractor, Record Building, Kansas City, Mo.
18. Journal National Fire Protection Association, Boston, Mass.
19. Journal Western Society of Engineers, Chicago, Ill.
20. Proceedings American Society of Civil Engineers, New York, N. Y.
21. Proceedings American Society of Municipal Improvements, New York.
22. Proceedings American Society for Testing Materials, Philadelphia, Pa.
23. Proceedings Engineers' Club of Philadelphia, Philadelphia, Pa.
24. Proceedings Engineers' Society of Western Pennsylvania, Pittsburgh, Pa
25. Professional Memoirs, Corps of Engrs., U. S. A., Washington, D. C.
26. Proceedings Institution of Civil Engineers, London, England.
27. Transactions, Canadian Society of Civil Engineers, Montreal, Quebec, Canada.
28. Railway Age Gazette, Chicago, Ill.
29. Better Roads, Jamestown, Ohio.

MATERIALS

The Testing of Sand for Use in Concrete—I, by Cloyd M. Chapman. (10) Feb. 5, 4¾ pp., ill. Field and Laboratory practice.

The Injection of Cement Grout into Water-Bearing Fissures, by Francis Donaldson. (1) Feb. 5, ¾ p.

DESIGN AND TESTS

Reinforced Concrete Columns; Some Considerations Affecting their Design. (9) Feb. 18, 1½ pp., ill. Discussion of various types of reinforcing as affecting design.

Approximate Stresses Produced by a Concentrated Load on a Continuous Slab Supported on Earth or Other Yielding Foundation. (9) Feb. 11, 1¾ pp., ill.

Characteristics of Concrete Design, by Charles E. White, Jr. (6) Feb., 4 pp., ill. Showing attractive designs of homes.

Report on a Series of Tests on Concrete Columns Reinforced with a Spiral of Steel. (19) Feb., 40 pp., ill.

Pergolas with Classic Pillars, by Charles Alma Byers. (4) Feb., 3 pp., ill. Concrete best adapted for construction of these features of city and country homes.

Decoration in Concrete Construction, by Paul Chesterton. (4) Feb., 10 pp., ill. Practical explanation of the methods of producing different types of surface finish.

Modern Concrete Porches, by Jack Desmond. (4) Feb., 3 pp., ill. Suggestive examples of porch design.

BUILDINGS

Construction of the Caisson Foundation for the J. P. Morgan & Co. Building, New York. (9) Feb. 18, 2 pp., ill. Work consisted of sinking to rock 18 pneumatic caissons, joined together to form continuous wall 7 ft. thick; 19 interior piers.

Mandatory Fireproof Construction and the Economy of Concrete, by J. P. H. Perry. (7) Feb., 3 pp., ill. Interesting discussion of two very important developments affecting reinforced concrete construction.

Ten Rules to Eliminate Building Failures. (9) Feb., ½ p. Important points to be observed in concrete construction.

BRIDGES AND RAILROAD WORK

Improvements on the Louisville and Nashville R. R. (10) Feb. 26, 7½ pp., ill. Account of miscellaneous use of concrete in tunnels, bridges and culverts.

A Reinforced Concrete Girder and Slab Bridge with Pre-Cast Members. (10) Feb. 5, 2½ pp., ill. Details of bridge 1075 ft. long.

The Coleman Cut-Off, by J. B. Skeen. (27) Feb. 13, 2½ pp., ill. Extensive use of concrete in development costing $8,000,000.

Design Features of the Reinforced Concrete Viaduct on Hopple St., Cincinnati, Ohio. (9) Feb. 25, 2½ pp., ill. Design features of the superstructure, consisting of a series of reinforced-concrete cantilever arms supported on reinforced concrete piers.

Methods of Concrete Construction in Track Elevation Work at Cleveland, Ohio. (9) Feb. 18, 1 p., ill. Description of the elevation of five miles of track, calling for 63,000 cu. yds. of concrete in street bridge abutments and retaining walls.

Design and Construction of the Bush and Gunpowder River Bridges Consisting of a Series of Reinforced Concrete Slab Spans. (9) Feb. 11, 4¼ pp., ill. Unusual design owing to the extremely soft character of sub-soil and the depth of stable foundation material—Penn'a R. R.

Design Features of the Reinforced Concrete Viaduct on Hopple St., Cincinnati, Ohio. (9) Feb. 11, 1¾ pp., ill. Extensive grade crossing elimination.

Methods of Constructing a Short Rock Tunnel on the New Low Grade Line Between Milwaukee and Sparta, Wis., Chicago & Northwestern Ry. (9) Feb. 4, 4 pp., ill. Tunnel Lining.

Bridge Design: A Letter from a Specialist (Daniel B. Luten). (6) Feb., 3¼ pp., ill.

Faultless Concrete Stations on the Lackawanna, by Curtis A. Wessel. (6) Feb., 2¾ pp., ill. Station at Montclair, N. J.

Concrete Bridge Again Victorious. (4) Feb., 3 pp., ill. Reinforced concrete selected for a mammoth viaduct in Southern California.

A Discussion of the Advantages and Disadvantages of Fixed and Three-Hinged Concrete Arches. With Solid and Ribbed Soffits and with Solid and Divided Piers. (9) Feb. 25, 3¼ pp., ill. Abstract of discussion Vol. XL; Proceedings Am. Soc. of C. E.

RESERVOIRS, DAMS, CANALS, ETC.

Hollow Concrete Dam for Coatesville Waterworks. (10) Feb. 26, ¾ p., ill. Details of dam 400 ft. long, 35 ft. high.

The Silver Lake Reservoir of the Catskill Water Supply System, New York City. (10) Feb. 5, 4 pp., ill. Details of reinforced concrete conduits.

A Reinforced-Concrete Sheet-Pile Sea Wall. (10) Feb. 5, 1¼ pp., ill. Details of sea wall 9500 ft. long at Bay St. Louis, Miss.

Construction Work for East St. Louis Flood Protection. (10) Feb. 5, 4¼ pp., ill. Description of miscellaneous use of reinforced concrete in levee construction.

Concrete in Drainage and Irrigation—Clean Materials and Dense Mixtures, by J. H. Libberton. (7) Feb., 2 pp.

Construction Features of the Intake Dam of the Tallulah Falls Development, for the Georgia Railway and Power Co. (9) Feb. 18, 3 pp., ill. Design and construction of dam 115 ft. high.

Structural Features of an Interesting Small Hydro-Electric Power Plant on the Sandusky River at Ballfille, Ohio. (9) Feb. 18, 2½ pp., ill.

The Proposed Rock Run Storage Dam for the Additional Water Supply of Coatesville, Pa. (9) Feb. 11, 2 pp., ill. Character of dam site, design and architectural treatment of concrete storage dam.

Efficient Plant for Building Locks on Ship Canal, by A. L. Erickson. (6) Feb., 4 pp., ill. Description of plant for concrete construction. The locks of the Lake Washington-Puget Sound Ship Canal.

Large Concrete Reservoir in St. Louis. (6) Feb., 2¾ pp., ill. For the Anheuser-Busch Brewery.

ROADS AND PAVEMENTS

Reports at the National Conference on Concrete Road Building. (10) Feb. 26, 7 pp., ill.

A Simple Curb Inlet for Street-Surface Drainage. (10) Feb. 26, ½ p., ill. Details of concrete curb.

Reinforced-Concrete Retaining-Wall of Pedestal Construction. (10) Feb. 5, 1½ pp., ill. Details of wall at street undercrossing in Ontario, Canadian Northern Rwy. 110 ft. on each side of bridge.

A Review of the Whys and Hows of Concrete Road Construction, by Lewis R. Ferguson. (7) Feb., 4 pp. Giving maintenance and construction costs, and methods of construction.

Investigation of the Causes of Expansion and Contraction of Concrete in Concrete Roads with Reference to the Prevention of Cracks. (9) Feb. 25, 4½ pp., ill.

Methods and Cost of Constructing at Clinton, Iowa, Concrete Pavement with Bituminous Surface. (9) Feb. 25, ¾ p.

Cost of Constructing a Concrete Pavement Surfaced with Asphaltic Oil and Stone Screenings for Huntington Drive, Alhambra, Cal. (9) Feb. 18, 1⅓ pp., ill. Five-inch concrete base, surfaced with ¼ gal. of asphaltic oil and 0.0063 tons stone screenings to the square yard.

Some Service Records of Bituminous Wearing Surfaces on Concrete Pavement. (9) Feb. 18, 1¼ pp., ill.

Concrete Road Construction—A Symposium from Committee Reports to the National Conference on Concrete Road Building. (9) Feb. 18, 3½ pp.

Methods and Costs of Repairing and Maintaining.
Concrete Aggregates.
Economic Methods of Handling and Hauling Materials.
Mixing and Placing.
Cost of Constructing.
Thicknesses, Crown and Grades.
Proportions and Consistency.

Method and Cost of Constructing Concrete Road with Bituminous Wearing Surface in California. (9) Feb. 11, 6 pp., ill. Data accumulated in constructing 14 miles of state highways.

Method and Cost of Constructing a Concrete Road with Concrete Line Poles and Concrete Fence, LaSalle, Ill. (9) Feb. 11, 1¼ pp., ill. Of interest because of completeness of design.

Unusual Concrete Road near Philadelphia. (6) Feb., 2½ pp., ill. Construction and cost of 700 ft. of road subjected to heavy automobile and wagon traffic.

Concrete Roads—A Symposium. (6) Feb., 2 pp. Extract from an informal discussion before the Am. Soc. of C. E. and reported in the proceedings of the Society, Vol. 39, No. 7.

Farmers and the Road Problem. (4) Feb., 2 pp., ill. Suggesting combined cheapness and permanence.

SEWERS, PIPE, TILE, ETC.

A Combination Cesspool and Septic Tank. (10) Feb. 5, ½ p., ill. Details of cesspool and septic tank for an office and store building.

An Unusual Concrete Pipe Plant at Auburn, Wash. (27) Feb. 20, 2⅓ pp., ill. Describes manufacture of 24 and 36-inch reinforced concrete pipe and piles. Gives details of forms.

Field Notes on the Construction of a Great Concrete Standpipe. (7) Feb., 6 pp., ill. Construction of standpipe 40 ft. inside diam. x 100 ft. in height.

Methods Employed in Making Reinforced Concrete Sewer Pipe in the Open During Freezing Weather at Louisville, Ky. (9) Feb. 25, ¼ p. Method of making 6000 ft. of reinforced concrete main sewers ranging from 6 to 10 ft. in diam.

Methods and Cost of Constructing Large Bridge and Concrete Sewers in Chicago, with Notes on the Cost Keeping System Employed. (9) Feb. 11, 4½ pp., ill. 2346 ft. long, 12 x 14 ft. elliptical section.

Prescribed Procedure for Laying 9-ft. Steel or Concrete Pipe in Existing 12-ft. Brick Water Supply Conduit at Baltimore—Old Conduit Alternately In and Out of Service. (9) Feb. 4, 1 p., ill.

Some Suggested Designs for Sewage Treatment Plants for Residences and Small Institutions. (9) Feb. 4, 4½ pp., ill. Septic Tanks.

CONCRETE PRODUCTS

Layout and Operation of Plant for Wet Process Block Manufacture, Using Metal Molds. (7) Feb., 3¾ pp., ill. Plant in which seventeen men make approximately 1900 per day.

MISCELLANEOUS

The Use of Concrete in the Construction of a Water Garden. (7) Feb., 3¾ pp., ill. Construction of a rock and water garden in space 100 x 150 ft. only.

Using Steam to Heat and Cure Double Walls in Cold Weather. (7) Feb., 2¾ pp., ill.

Making Concrete Posts Economically. (7) Feb., ½ p. Use of incline of idle coal chute on railroad line.

Concrete Poles are Strong Enough. (6) Feb., 1 p., ill. Test of three poles.

Curing Cement Products by Steam. (4) Feb., 1 p. Experience of a large operating concern.

Revelation in Block Possibilities. (4) Feb., 2¼ pp., ill. One of the most successful block plants in the world.

The Sieving of Cement. (1) Feb. 12, 2½ pp. Gives conclusions of paper published by Rudolph J. Wig and J. C. Pearson.

Notes on Sand, Stone and Gravel for Salt Water Cement, by Harrison S. Taft. (1) Feb. 19, 4 pp. Gives chemical properties of cement, and character of sand, gravel and stone to be used in concrete standing in sea water.

PART II.

PROCEEDINGS OF TENTH ANNUAL CONVENTION.

Papers, Discussions and Reports.

DISCUSSION.

REINFORCED CONCRETE PAVEMENTS AND ROADWAYS.*

By B. S. Pease.

Mr. B. S. Pease.—I am afraid from the discussion on reinforced concrete roadways this afternoon that a number of gentlemen are attempting to arrive at the proper weight of reinforcement on the basis of structural formulas. If you do that you will never get anywhere with reinforced concrete pavements, because the assumed stresses in the pavement will require an amount of steel that will cost as much as the entire balance of the pavement, which would be prohibitive. I fully realize that it is preferable, as an engineer, to work with formulas, but if our formulas do not give us what we want, and we have certain definite types of construction that have proven satisfactory, why not consider them in making our designs? Mr. Pease.

Mr. L. J. Mensch.—Last evening Mr. Finley told us to be conservative in the use of reinforced concrete. Tonight we are told that concrete reinforced by one-twentieth of one per cent of steel will not crack, or will increase the strength of the concrete. That is contrary to any test that I ever saw or ever heard of being made. In my experience, I find that you cannot prevent cracks in concrete unless you reinforce the concrete by at least three-tenths or four-tenths of one per cent of steel. Mr. Pease stated or advocated the use of one-twentieth of one per cent against four-tenths,—the practice in other construction. I think the good effects of the reinforcement of the pavements in the cities mentioned is to be ascribed to the greater care taken in laying them, because they were willing to spend more money and had better work than in the ordinary concrete pavement; but from my experience I can say that it is money thrown away to try to reinforce a pavement with such a small amount of steel. I did not hear what Mr. Pease said the cost was per square yard, Mr. Mensch

* See Journal, Vol. II, No. 1, pp. 112-118.

Mr. Pease. MR. PEASE.—From seven to fifteen cents.

Mr. Mensch. MR. MENSCH.—Well, let us take fifteen cents a square yard; say, roughly speaking, two cents per square foot, or at the present price of steel, 1.3 or 1.4 cents per pound, that would be 1.5 lb. per sq. ft. Now, if we use instead of wire mesh, rods at 1.4 per sq. ft, we would have about 1.5 lb. of steel per sq. ft. or about 0.2 in. per lineal foot, which would be about three or four times as much steel as Mr. Pease advocates. And from my experience, I can assure you it does not cost half a cent, possibly not a quarter of a cent, per square foot to place steel rods. Wire mesh comes in big rolls, does not lay flat and it is difficult to get in the lower side of the slab. I cannot see how wire mesh placed only in the lower portion of the slab will prevent cracks. You do not prevent cracks by having the reinforcement only in the under side; you must reinforce both the under side and the upper side. In designing water tanks or reservoirs on bad ground, we always assume that there might be settlement for one, ten or fifteen feet in diameter, and we reinforce both the under and upper side to prevent cracks, because in that case you would lose water. I never heard of any experienced man who designed otherwise.

Mr. Pease. MR. PEASE.—I thought I made myself clear when I said that trying to design a reinforced concrete slab on the basis of formulas will not secure the results desired. That is, if you are going to use reinforcement for pavements you must use experience rather than structural formulas in determining the amount. The amount of steel required by these formulas would be prohibitive and the best answer that I can give is to refer you to present construction in which reinforcement has been used, regardless of whether it is wire mesh or not. The results that are obtained show conclusively that you can get a benefit by putting your reinforcement in there; and this has undoubtedly produced a feeling among a very large number of engineers that it is possible to secure this benefit. This subject of reinforced concrete pavement, as stated in my paper, is a new one, and we all realize that we may have to make many changes.

Mr. Wig. MR. R. J. WIG.—If I understood Mr. Pease correctly, he stated that with the softening of the sub-base along the outer edge from moisture, there would be a tendency toward cantilever

action and for a crack to occur at the top of the slab. He further states, reinforcement should be placed at the bottom of the slab so that with heaving, due to frost, it would not crack at the bottom. I do not understand why he would not recommend reinforcing the top of the slab to prevent the first crack and if there was a tendency to heave, that we should not need reinforcement at the bottom also. Mr. Wig.

MR. PEASE.—I stated that if the moisture is in your foundation and it freezes, the pavement will heave at the outer edge and crack the slab on the under side. If it is a case of the foundation being soft on the outer edge it will be depressed on the outer edge and crack at the top; and I also stated that I did not want to go on record as saying that we should favor slighting the drainage of your foundation in any way in order to use reinforcement; that you ought to drain your foundation. I also said that if the conditions are going to vary, the engineer must decide if the foundation is bad and whether it will require two layers of reinforcement, viz., one on the top and one on the bottom. Mr. Pease.

MR. WIG.—It has been generally observed that the longitudinal cracks in concrete roadways occur in the spring and not with the heaving at the time of frost. If that is the case, it may be that the crack occurs in the bottom with the frost and is not apparent on the top until the thaw occurs, dropping the outer edge of the slab. Mr. Pease states that the reinforcement is placed in the top of the slab to take care of the movements due to temperature changes more as a convenience of construction, than as a proper design to obtain the greatest efficiency in the use of the metal. Certainly there is no restraint on the top side of the slab excepting that transmitted from the bottom, and I can see no reason for putting in reinforcement in the top of the slab to take care of movement due to temperature, as the bottom of the slab is restrained and the maximum stress must be at the bottom and not at the top. Mr. Wig.

MR. PEASE.—Referring to Mr. Wig's statement that he thought the reinforcement should be in the bottom, I still cannot agree with him. I think that unless it is a case similar to the one I have previously referred to of a pavement that was constructed in California on filled ground, the reinforcement should be placed on the top regardless of whether the top and bottom of the slab is under different degrees of restraint. Mr. Pease.

Mr. Doyle. MR. H. S. DOYLE.—Where have pavements been laid with the reinforcement in the bottom and not in the top?

Mr. Wig. MR. WIG.—It has been the general practice in the past to recommend the placing of the reinforcement in the top of the slab to take care of temperature changes, without provision being made for moisture changes. We know of no road in which metal has been placed in the bottom of the slab, but we do know of a great many roads where metal has been placed in the top and slabs have cracked indiscriminately. Of course, we do not know that the cracks are due to movements caused by temperature changes, but we know that reinforced slabs have cracked and reinforcement has not prevented cracking.

Mr. Pease. MR. PEASE.—Mr. Wig made a statement that there are lots of reinforced concrete pavements with the reinforcement placed in the top where the slabs have cracked. That is very interesting information to me, and I certainly would like to know where they are.

Mr. Wig. MR. WIG.—Mr. McIntyre, who was joint author with Mr. Tunicliff of the report of the Committee on Expansion and Contraction of Concrete, presented at the National Conference on Concrete Road Building, will be pleased to furnish Mr. Pease with the location of the cracked reinforced concrete slabs.

Mr. Boynton. MR. C. W. BOYNTON.—I believe we can come to more definite conclusions if we consider for a moment the comparative yardage of plain and reinforced concrete pavement which has cracked. I believe I am safe in saying that a very much smaller percentage of pavement laid with reinforcement has cracked than that laid without. It is only by such considerations as these that we can get anything on which to base our calculations.

Mr. Boorman. MR. T. H. BOORMAN.—Mr. Pease referred to a new system of reinforcing. I would like to state that prior to 1884, a little over thirty years ago, The Matt Taylor Paving Company used the Stewart patent reinforcement in granolithic pavement. That is over thirty years ago and since then the patents have expired but the system has been used as reinforcing in granolithic work.

Mr. Kinney. MR. WILLIAM M. KINNEY.—It seems to me that we lose sight of the real value of the reinforcement when we put too much emphasis on its vertical location in the pavement. Reinforcement is placed primarily to take care of the tensile stresses in

the concrete due to contraction and expansion, be this from temperature or moisture changes, or both. No doubt it has some value in bridging over poorly compacted sections of the sub-grade, but the location of such places is seldom known and placing the reinforcement in either the top or bottom of the slab will not overcome all stresses. It seems advisable, therefore, to ignore this value of reinforcement and consider that it can be placed anywhere in the slab two or more inches below the top surface. Mr. Kinney.

MR. W. W. DEBERARD.—As to the top and bottom reinforcement, many blocks of reinforced pavement in Detroit, Michigan, have been laid last year and the year previous, and I think, from observation last fall, that those pavements have stood up remarkably well. Mr. DeBerard.

MR. BOYNTON.—Mr. R. D. Baker of Detroit has built very large yardages of pavement within the city limits of Detroit, Highland Park and other adjoining cities, and he guarantees the pavement reinforced with the amount of steel which we are specifying, for five years against cracking. He will not guarantee a pavement without reinforcement. Mr. Boynton.

DISCUSSION.

SOME ESSENTIAL REQUIREMENTS IN CONCRETE PAVEMENTS.

By R. C. Stubbs.*

Mr. Wig. Mr. Rudolph J. Wig.—I would like to ask Mr. Stubbs if he will give us a little more in detail the experiments which he made of porous soils to determine their elasticity.

Mr. Stubbs. Mr. Stubbs.—These experiments extend over a period of some twelve years; the samples tested are Texas clays, whose chemical composition I do not know, taken from the site where I was working; I found that there was a great variation in their compressibility. We have what is known as the black land of Texas; it is a black clay, which possibly has the greatest voids as it has the greatest compressibility of any clay that I have ever found. These clays differ so in character that I cannot describe them from memory and I do not have the records with me. The various clays were very easily compressed; any clay is very easily compressed and it is not difficult to make the test. It is very easy to get the amount of compression that is desired on any particular sample.

Mr. Wig. Mr. Wig.—I am particularly interested in the method of conducting the experiments; not the results obtained but how the samples were compressed; how they were kept during the test and during the recovery and whether they were prevented from absorbing moisture from the atmosphere.

Mr. Stubbs. Mr. Stubbs.—After the sample was compressed I placed it back in the earth. The average depth that I found afforded the best protection, was eighteen inches below the surface; the sample was compressed to the smallest volume, placed back in the earth, in the smallest space possible and then left subject to the action of the weather and other elements. I think the changes in the samples were caused in some cases by the variations due to the seasons. The moisture squeezed out during the laboratory

*See Journal, Vol. II, No. 1, pp. 108-111.

compression can be restored very readily; in the actual sub-grade you have to wait for the seasons of moisture, and it takes a year to get it back to its natural state, but it will come back and it will raise a great weight with it. I have built pavements in Texas that were over-compressed and the entire pavement now is raised three inches above where it was when it was built, by actual levels taken, and it is there in good shape. It is not my particular pavement I have reference to, but other pavements. They are in good shape although the entire pavement is raised up. Mr. Stubbs.

MR. WIG.—I would like to ask what Mr. Stubbs' experience has been with rough and smooth sub-grades. Mr. Wig.

MR. STUBBS.—I am very glad that question was asked, because I believe that as much depends on the smoothness as on almost any other feature of the sub-grade. The movement of the earth is a frequent cause of trouble. If the bottom of the concrete pavement is very rough, the earth catches hold of it and when the movement of the earth starts, there results a very heavy pressure; the sub-grade should be absolutely as smooth as you can get it. Mr. Stubbs.

TOPICAL DISCUSSION ON THE MANUFACTURE OF CEMENT PRODUCTS.

The President.

PRESIDENT RICHARD L. HUMPHREY.—This hour before the regular session of the Convention will be devoted to a general discussion of the manufacture and use of cement products such as building blocks, drain tile, sewer pipe, fence posts, etc. The meeting will be in charge of the Chairman of the Committee on Cement Products.

In the early history of this Association these experience meetings were most helpful, and did much in the education of the members who obtained at these meetings a more detailed discussion of their problems than was possible at the regular sessions of the Convention.

It is interesting to note the development which has taken place since the formation of this Institute in Indianapolis in 1905. The organization, as you know, was primarily for the promotion of the manufacture and use of cement building blocks which industry was then in its infancy; these blocks, were, for the most part made by the dry process, producing a block which was quite porous and which would absorb a large quantity of water. To overcome this difficulty, various methods of waterproofing were developed, and the country was flooded with waterproofing compounds, coatings and other preparations, most of which had little or no value. In one of the first addresses that I delivered before this organization, I strongly advocated the necessity for a wet mixture, and my persistent advocacy of the wet mixture led to the climax at the second convention in Milwaukee where I was waited upon by a committee of members of this organization and was told that unless I would promise to cease my advocacy of the wet mixture, they would not re-elect me President of the Association. Now the dry mixture block is becoming a rarity, and blocks by the wet process are becoming the rule. The character of the blocks turned out by the dry process has been so unsatisfactory as to bring them in disfavor with the public; the

block maker has therefore been forced to make a better block, and he had to come to the wet process. Today there are a number of plants making a highly satisfactory building block by the wet process, and I believe as time goes on, and the quality of the block improves, it will meet with increasing popularity. The President.

The same is true in the history of the cement drain tile, and to a lesser extent of the cement sewer pipe, although in the East very excellent sewer pipe have been made by the wet process for some time. The cement pipe is meeting with increased favor, although it is not used to nearly the same extent that it is used in Europe. The plants in this country are for the most part not as well organized as those abroad, and the quality of the product is not nearly as good.

Another cement product whose use is extending rapidly is the concrete fence post. Its use at first was more or less experimental, but the persistence of its makers has resulted in a superior post whose durability and strength, and the reduction in the cost of maintenance by reason of the highly satisfactory alignment possible, has led to its extensive use; its introduction by the railroads for fencing right of way has been the result of its low cost of maintenance, and especially on Western roads, of its indestructability by fire.

The railroad tie has not met with satisfaction, since no type has been proposed which will not disintegrate under the impact of the locomotive. I am sure, however, that this problem will be met, and the concrete railroad tie will be in due time be as extensively used as the fence post.

There is unquestionably a great field in the manufacture of cement products, and the development of their use will depend on the care with which they are made. Perhaps the most helpful discussion would of the fundamentals to be observed in the manufacture of cement products. One of the tendencies today is to exercise insufficient care in the proportioning and the mixing of the concrete; too little water is used, and the material is insufficiently mixed. I believe the use of small, well-graded aggregates, and the mixing of them for at least a minute and a half will produce a homogeneous and dense mass. By carefully proportioning the aggregates and by longer mixing, denser mixtures may be obtained having the same strength as richer mixtures, less thor-

The President. oughly mixed. It is then highly important that the material shall be properly cured. When a sewer pipe or drain tile is properly made and cured, it should ring like a piece of cast iron; it should be so dense that the water will stand on it, and should break with a sharp fracture. As most of you are aware, the product of today does not fulfill these requirements.

The most important asset in the promotion of the cement tile business is the production of tile of such high quality that it requires little advertising for their introduction.

Mr. Ewing. MR. DAVIS EWING.—About four years ago, I excavated for the curbing for a pavement and found a line of concrete sewer tile, which had been previously laid about thirty-two years. They had been in use during all this time and were in just as good condition as the day they were laid. They evidently were made very wet, and of a granite concrete. They were so dense that they would ring like a bell when struck. I am not in the manufacture of tile, but it would seem to me that if you can make tile as good as those, you would have no trouble in disposing of them. I am making concrete blocks in an hydraulic press, but make them so wet, that after they are cured the water will stand on them until it evaporates. I suppose the absorption would be from three to five per cent, not over that.

Mr. Cline. MR. A. E. CLINE.—In regard to the making of concrete sewer pipe in Germany, I would like to know whether it is made by the tamped or poured process.

The President. PRESIDENT HUMPHREY.—The German success in making cement pipe is, in my opinion, entirely due to the care which they take in proportioning and mixing the concrete. They use very fine crushed stone, very little water, and they mix the material long and thoroughly. They obtain a butterlike consistency. The factories are equipped with tamping machines for the manufacture of the larger pipe, while the smaller pipe are generally made by hand. The pipe when finished is dense, possessing a very smooth finish, and will ring when struck with a hammer.

If the mixers in this country were revolved less rapidly, and for a longer period of time, using a moderate amount of water, the resulting mortar or concrete would be very much more dense and strong. By this procedure, the air and water voids would be eliminated, and the ingredients of which the mortar or con-

crete is composed, brought into a closer contact, which is necessary to develop the maximum density and strength in the material. The type of mixer also has a great deal to do with the character of the resulting material, and it should in general be one which would produce a rubbing action which is necessary in order that each aggregate may be thoroughly coated with cement. A properly mixed mortar or concrete should be of such a consistency that it can be readily placed in position, and one which it would not be necessary to tamp in order to compact. You cannot materially increase the density of a mortar or concrete by tamping, since the air and water voids in the interior are not eliminated, and it is only through their elimination that the density may be increased. The President.

Mr. Cline.—I think our result was due to the fact that we used an agitator in mixing, and we found that the concrete would not separate after mixing a half an hour. That may be a long time, but for our work it had to be mixed that long. Mr. Cline.

As to the difference between dry and wet mix, I would state that I made blocks in a pressure machine, using a pretty dry mixture, and found that the block would absorb at least ten per cent of water, and under a forty pound pressure it would go through the web; I used a 1 to 5 mixture, sand the coarsest aggregate we could get. The same aggregates mixed 1 to 7 and poured wet into a wooden mould, the block would absorb only two per cent, and the water did not go through the web under a forty pound pressure. The leaner mix was mixed sufficiently to get the air bubbles out.

The jackets were taken off at once and set on one side, making pipe in two and a half foot lengths; we tried making them wetter and leaving them in the jackets over night, and made a far better pipe.

If the plants could have a galvanized iron inner jacket that could be left on the pipe until the following morning, I am satisfied that a far better product could be made.

Mr. P. H. Atwood.—In grading our aggregates for tile and blocks the question arises, shall we call sand, the material passing a one-eighth inch screen and call coarse aggregate, all material over one-eighth inch, or shall we use a quarter inch screen? I understand that in road work as a general rule the mixture is $1:1\frac{1}{2}:3$. Mr. Atwood.

Mr. Atwood. In some places in Iowa they are using 1:1½:2 mixture, and I have been wondering how satisfactory a mixture of 1:1½:3 using sand passing a one-eighth inch screen would be for drain tile. Has anyone had experience with this mixture?

The President. PRESIDENT HUMPHREY.—That mixture would be too rich as to cost, but would give a excellent tile as regards strength. A 1:1½:3 mixture, if the material is well graded, gives a very dense mortar, and would develop a greater compressive strength of than a 1:2:4 mixture. A 1:1½:3, concrete mixed dry, would not give the results that you desire. It is not only necessary to properly grade the aggregates, but it is necessary to thoroughly mix them. You should not have a sloppy mixture but you should prolong the mixing so as to get what water there is in the mortar or concrete thoroughly mixed through.

Now the purpose of water is twofold: one is to set the cement and the other is to help the process of eliminating the voids and bringing the particles into closer contact. The time will come in this country when we will use lean mixtures with good results, and only under extraordinary conditions will we resort to mixtures as rich as you have specified. I do not think a mixture as rich as that is necessary, but it may be that it will solve your difficulties better than the leaner mixtures. Of course, the more cement you use the more you are going to add to the cost.

Mr. Cline. MR. CLINE.—What is the largest size of your aggregate?

Mr. Atwood. MR. ATWOOD.—One-half inch.

Mr. Cline. MR. CLINE.—That makes considerable difference in the amount of sand you can use. Of course, the larger your aggregate the more sand you can use. I think if you have a half inch or smaller aggregate, 1:2:4 is going to give you more sand than you need.

Mr. Williamson. MR. F. L. WILLIAMSON.—Referring to concrete pipe, perhaps you are familiar with the work the U. S. Reclamation Service has been doing in this line. I had the pleasure of listening to a talk recently by Mr. Arthur P. Davis, Chief Engineer of the Reclamation Service, and learned that they had been using cement pipe for a long time. In one instance they are using cement pipe 46 in. in diameter under a head of one hundred feet, pipe made in lengths of eight feet, using a wet mixture.

He called attention to the fact that they made it a point to lay this pipe under cold weather conditions, when they would have the greatest contraction, and used nothing but a cement grout joint and had perfect results in the use of this pipe. If any of you are doubtful as to the success of concrete pipe if you take the matter up with the Reclamation Service and see what has been done, you will be convinced that they are an absolute success when properly made and properly placed. Mr. Williamson.

CHAIRMAN ARP.—In answer to Mr. Atwood's remark about the dividing line between fine and coarse aggregate, I think it is generally admitted by engineers that one-fourth inch screen is the dividing line, and personally I can see no reason for changing that for cement products. Mr. Arp.

MR. E. S. HANSON.—I am glad that President Humphrey has brought forth the suggestion, that we must develop some method whereby the mold can be left on the tile for a time. I believe we are coming to that. At one time I went into some figures regarding this method of manufacture, with the idea of developing a container of paraffined paper, or some such material, which would go inside the regular mold and be left on the tile. The figures I was able to secure would not admit of going into this on a commercial scale; nevertheless, I believe some such method, which will be practicable from an economic standpoint, will ultimately be devised. Mr. Hanson.

PRESIDENT HUMPHREY.—I believe that it will be possible to develop a light liner for the cement pipe or tile mold which will support the tile without distortion until it has acquired the strength requisite to be self-supporting. Through the use of such a liner it will be possible to use wetter mixtures, which will result in more satisfactory pipe or tile. The President.

CHAIRMAN ARP.—I believe there is one concern now that is turning out an interliner for the purpose of assisting a tile in standing up, and it is only a question before the larger concerns will work along those lines. Mr. Arp.

MR. ATWOOD.—I don't believe you will ever see that done. It may be all right for terra cotta tile, but for cement tile it will not work because of the trouble keeping those jackets clean. We cannot do it and compete with the clay tile. You state that slush tile are more dense and stronger than dry tamped tile. Any of Mr. Atwood.

Mr. Atwood. the machine tamped or any of the power machine tile are more dense than those made from a slush mixture. If you make your tile so wet that they have the web-like markings on the outside and on a spiral machine which gives a trowel finish on the inside, they stand up, and will not need anything to hold them in shape, and will be denser than your slush tile, provided they are kept damp while curing. They are not nearly as brittle, will stand shipping better, and will carry a greater load.

The President. PRESIDENT HUMPHREY.—I think you can use too much water in mortar or concrete, and the phrase "slush tile" is liable to lead to very bad practice. The average person would interpret this to mean a mortar or concrete of a fluid consistency, which is entirely unsatisfactory. Water voids in mortar or concrete are as objectionable as air voids, and the more water you use in mixing, the more water voids you will have. The happy medium is to use just enough water to enable you by thorough mixing to bring the particles into contact, and to coat each particle with a requisite amount of cement.

The manufacturers of cement products made the mistake of using too little water, and a very dry highly absorptive product was the result. Now, I am afraid, there is a tendency for the pendulum to swing the other way, and to use too much water. Each manufacturer should study his own product, and endeavor to secure the highest quality possible. I think there is nothing so beneficial to the manufacturer in the development of a high grade product than the development of standard specifications,—for this compels the manufacturer to subject his product to tests, which is after all the best measure of quality, and those who do not come up to the standard requirements can intelligently improve the quality of their product.

Mr. Williamson. MR. WILLIAMSON.—With reference to the tamping of tile, I might relate an incident that I saw recently. In a tile plant, using a high speed tamper, the manager demonstrated to me the density and strength of the pipe as it came from the molds. The tile encased in the outer removable shell was carried from the machine and as it seemed to me, roughly handled and placed upright on the small end. The shell was removed and a demonstration was at once made to show the strength of the pipe. With a trowel a hole was cut in the side suitable for attaching

an elbow, and then the cut was made vertically from the top to the bottom. The tile stood until a considerable portion of the shell had been cut out from the top to the bottom, then collapsed into a heap of mortar. This pipe, as I now recall it, was 8 inches in diameter and 30 inches long. Mr. Williamson.

Mr. Cline.—With a wet mix there is only one method that I know of where you can be sure of getting a dense concrete without stirring or puddling, and that is the sand mold process, where the sand absorbs the excess of water in the concrete. I have made a good deal of stone that way and I have yet to find an air pocket of any kind that I have had to cut. But it is too expensive to use in making tile. Mr. Cline.

DISCUSSION.

SPECIFICATIONS FOR DRAIN TILE.

By A. Marston.*

Mr. Blair. Mr. W. P. Blair.—I would like to ask Professor Marston what proportion these 30-inch pipe were and what reinforcement was used?

Prof. Marston. Professor A. Marston.—It happens that the 36-inch pipe were cement pipe in this case. I did not mention that in my paper. They were made 1:3½ and part had two and part three double hooks of wire as reinforcement. None of the pipe collapsed. They cracked in the ditch. Most of them were taken out and set on the ground without collapsing. They were made in a machine with a tamp. I did not see the factory or process of manufacture.

Mr. Smith. Mr. W. W. Smith.—How thick was the shell of the 36-inch tile?

Prof. Marston. Professor Marston.—Three inches.

Mr. Blair. Mr. Blair.—I should like to ask whether crushed material was used in the mix?

Prof. Marston. Professor Marston.—The material was river gravel taken from the Des Moines River adjacent to the plant.

Mr. Raymond. Mr. H. L. Raymond.—How long had the tile been cured?

Prof. Marston. Professor Marston.—I do not know. I used this particular case of the tile cracking simply as an illustration of the point I was making. In the written paper there is no mention of it.

Mr. Cline. Mr. Cline.—Do you know what was given as the weight on this six to nine feet; have you any data on that at all?

Prof. Marston. Professor Marston.—In this case a certain number of these pipe were removed from the ditch, taken to the laboratory and tested for strength. Then the weight resting on them was calculated for the five-foot and also for the nine-foot depth, and

*See Journal, Vol. II, No. 1, pp. 54–59.

a comparison made between the strength of the pipe and the weight that caused them to crack. I may say that the comparison agreed quite closely. Prof. Marston.

MR. CLINE.—What was the load? Mr. Cline.

PROFESSOR MARSTON.—Twenty-one hundred pounds per lineal foot for the 5-foot fill and 2,800 pounds for the 9-foot. Prof. Marston.

MR. J. L. ZEIDLER.—Is there a possibility that it was green pipe, that it had not been aged sufficiently or had not been properly cured? Mr. Zeidler.

PROFESSOR MARSTON.—My impression is that the pipes were in the neighborhood of two months old, and I think that they had not yet attained their ultimate strength. We did not think that that was going to make them safe for that particular depth, so through the deep part they were laid in lean concrete bedding. Prof. Marston.

DISCUSSION.

RESULTS OF TESTS OF PLAIN AND REINFORCED CONCRETE TILE.

By George P. Dieckmann.*

Mr. Atwood. Mr. P. H. Atwood.—These tests were not carried on with the intention of seeing how much strength we could get out of the tile, as to obtain the comparative strength with the different number of hoops. These tile were made in the fall, were kept in the steam room, were then rolled out of doors and kept there for about twenty days. It was the intention when the pipe were made to have them tested at thirty days, but they were tested at sixty days because of the illness of Professor Marston's assistant. In order to harden the tile at the end of the twenty days, they were rolled into the engine room of our factory and were kept in that dry, warm atmosphere for the remainder of the time. When they were placed there we only expected to test them at the end of about one week.

Mr. Blair. Mr. W. P. Blair.—Were they watered from the time they were taken from the machine until they were placed outside?

Mr. Dieckmann. Mr. George P. Dieckmann.—Tiles 4, 5, and 6 were all wetted before testing and showed a slight decrease in strength.

Mr. Chubb. Mr. J. H. Chubb.—I understood Mr. Dieckmann to say that Series DO and WO, in one case were dry tile and in the other case wet. That is, during curing, one was sprinkled and the other was not sprinkled. Is that right?

Mr. Dieckmann. Mr. Dieckmann.—No, DO was dry tile. The whole series was practically made alike, cured for forty-eight hours in the steam chamber and then rolled out doors. About two days before testing, tiles Nos. 4, 5, and 6, marked W for weight and O for no reinforcement, were thoroughly wetted and these tiles were placed in the testing machine with all the moisture in it and the tiles DO were tested absolutely dry.

There is a great difference of opinion among engineers, whether the tile should be tested dry or whether it should be thoroughly saturated with water and then tested. Some engineers have advocated the idea that concrete, when it is thor-

* See Journal, Vol. II, No. 1, pp. 60-64.

oughly saturated with moisture, is not strong, and for this reason we found it advisable to determine if there was really a difference between dry concrete and that saturated with moisture. We have found a slight decrease in strength. Mr. Dieckmann.

MR. J. L. ZEIDLER.—What was the age of the pipe when the test was made? Mr. Zeidler.

MR. DIECKMANN.—All tile were sixty days old. Mr. Dieckmann.

MR. ZEIDLER.—Mr. Atwood explained that the pipes were moved into the engine room in cold weather. Was the weather very cold? Mr. Zeidler.

MR. DIECKMANN.—All tile were made on the 14th and 15th of February. The weather was very moderate. Mr. Dieckmann.

MR. ZEIDLER.—Is there a possibility that the pipe was injured by being taken in its green state from a cold atmosphere or semi-cold, into a heated room and cured; that that had something to do with the weakness of the pipe. Mr. Zeidler.

MR. DIECKMANN.—We know that tile that is steamed for about forty-eight hours has practically the same strength as tile cured in the usual way. So there is no chance that the product was not properly cured. Mr. Dieckmann.

MR. ZEIDLER.—I would like to ask whether 15,000 pounds would be a pretty fair test? Mr. Zeidler.

MR. DIECKMANN.—Oh, yes. The specifications which will be drawn will require that the tile, for a certain depth of ditch, to stand a certain load, and it will be up to the tile manufacturers to produce such a tile. If he can produce it without reinforcement it is all right. It doesn't matter to the user of drain tile whether he reinforces or whether he makes plain tile so long as it has the desired strength. In this paper we simply want to point out the advantage of the different reinforcements for drain tile, so the tile manufacturer may know what strength to expect of his different tile. Mr. Dieckmann.

MR. BLAIR.—Have you any tests showing the strength of pipe after forty-eight hours curing in a steam chamber? Mr. Blair.

MR. DIECKMANN.—We have no tests on tile. A few years ago I presented a paper on steam curing of cement products on small specimens and this series included about five hundred cement briquettes. The briquettes were steamed, I think, under ten different conditions. A series was made under different Mr. Dieckmann.

Mr. Dieckmann. steam curing periods which showed that with forty-eight hours steam curing you obtain practically the same strength that you obtain with thirty days ordinary curing. Of course, what is true for small specimens ought to be true for large specimens.

Mr. Bingham. MR. L. L. BINGHAM.—There is one point that I would like Mr. Dieckmann to explain and that is what he means by steam curing. You know very well there is such a great difference in the temperature of curing rooms, and forty-eight hours at one plant might be vastly different from the same time at another. I think we ought to know the temperature of the curing room before we come to any conclusion as to the strength at forty-eight hours as compared with that at thirty days.

Mr. Dieckmann. MR. DIECKMANN.—A steam that is saturated with moisture and generally from 90 to 130 degrees Fahrenheit, is considered to be the best; while a higher steam is likely to drive off the water which is necessary to harden the cement. It has been my experience that steam of a temperature from 90 to 130 degrees, kept moist, gives the best satisfaction.

Prof. Marston. PROFESSOR MARSTON.—I would like to say that Mr. Dieckmann did not get the data of these tests in time to prepare it as he would have liked. This work takes lots of time, and I suppose that the gentlemen who have spoken hardly realize that we have had two men at the experiment station engaged steadily in these investigations for about six months, putting all their time on it. I presume the experiments have cost the experiment station a couple of thousand dollars. Just before I came away I looked over the complete report that Mr. Dieckmann could not get in time to prepare his paper, and observed a number of additional data in that complete report. I would like to suggest that it may be well for Mr. Dieckmann to submit a more complete table of data for the printed proceedings. I noticed one interesting thing, and that was that the strength of the hooping on the specimens was remarkably constant. The number of hoops ranged from two to six and the strength added by each pair was quite constant. The hoops, in some cases, pulled through the concrete on the inner side of the tile, and in some cases when they broke they stretched straight across the bottom several inches clear of the concrete. When the pieces of pipe were separated in some cases you could pull the wire

through the concrete a little, showing that it had slipped. We would like to find out how to reinforce concrete pipe in such a way that the load carried before cracking results, as well as the ultimate load, will be increased; I do not see any way to do this except to make up a series of concrete pipe, reinforced in all imaginable ways, and test them. This will, of course, require a lot of time and money. I am sorry in my own paper the matter discussed was simply a side reference to a case where a tile had cracked. It happened also that that particular tile was a concrete tile; the tests of tile which have cracked, of which we have records, are pretty well distributed between clay and concrete. Prof. Marston.

MR. ZEIDLER.—Was that a galvanized or a plain iron hoop? Mr. Zeidler.

PROFESSOR MARSTON.—Galvanized. Prof. Marston.

MR. DIECKMANN.—I would like Mr. Zeidler to give us his experience in using wire mesh hoops. Mr. Dieckmann.

MR. ZEIDLER.—In the last five years I have experimented in the manufacture of wet mix hand-made concrete pipe. I found that the galvanized wire mesh that we used was not successful; we found the very condition of which Mr. Dieckmann spoke, that if we broke a pipe the wire would slip a little bit; but where the ungalvanized wire was used, it was impossible to pull it loose from the concrete. In other words, the plain wire is better for reinforcing than galvanized wire. Mr. Zeidler.

MR. ATWOOD.—The galvanized hoops, referred to by Professor Marston in the 36-in. tile, were hard-drawn steel wire electrically welded, in each tile the hoops were in two sets, one a half inch from the inner core and the other a half inch from the outer core. The first hoops used were tied by hand and there was a variation in the spacing, so that in one or two of the tile the hoop came within a quarter of an inch of the inner surface of the tile. The new hoops are electrically welded, have prongs of heavy wire projecting out half an inch to hold them in position. Mr. Atwood.

PROFESSOR MARSTON.—The wire in the pipe is on a curve and when you put a strain on it it tends to break on each side of the pipe. If the two wires are held together they are not going to pull out of the concrete the way they did in these tests. I would like to make that as a suggestion of a possible improvement. We cannot tell just what the effect will be until more tests are made on pipe reinforced in just that way. Prof. Marston.

The President. PRESIDENT HUMPHREY.—In reference to Mr. Zeidler's remarks about galvanizing, I think there must have been some unusual condition connected with that particular lot of galvanized metal that gave the results that he reports.

Mr. Zeidler. MR. ZEIDLER.—The explanation given was that galvanized wire has an oily coating to which the concrete will not adhere. That was the explanation that they gave us at the time. I understand that the galvanized wire mesh is now dipped in acid to remove this oil. This experience was five years ago and at that time, in testing, the galvanized wire pulled loose from the broken pipe. You could see the crust of the galvanizing stick to the concrete and the wire itself was pitted.

The President. PRESIDENT HUMPHREY.—The oil will be absorbed by the cement in the concrete so that unless there is a great excess of oil on the wire, which I think would not be the case, while it might tend to reduce the bond, it would not destroy it.

Mr. Zeidler. MR. ZEIDLER.—That might be true, Mr. President, but the pipe that was reinforced with plain wire made under the same conditions, stood thirty per cent higher test than the galvanized wire.

Mr. Raymond. MR. H. L. RAYMOND.—Will the dry mix concrete adhere to this reinforcement as well as the wet mix?

The President. PRESIDENT HUMPHREY.—The exact nature of the bond between metal and concrete is not fully known; it is believed that the cementing material flows into the microscopic pores in the metal and these anchors and the friction, offers the resistance that grips or holds it in the concrete. So it would follow that the wet mixture would develop greater bond than the dry mixture.

Mr. Dougherty. MR. G. H. DOUGHERTY.—It would be of interest to quite a number of people to know whether the additional strength secured by reinforcing concrete tile was proportional to the cost or whether the cost was greater in proportion than the greater strength obtained.

Mr. Atwood. MR. ATWOOD.—Twenty-eight inch tile without reinforcement, sell for $650 per thousand feet; reinforced tile sell for $720 per thousand feet, using three hoops (No. 7 wire) to the tile, and the gain in strength is about twenty-eight per cent.

Mr. Richardson. MR. RICHARDSON.—Mr. President, I would suggest using a smaller wire and more hoops. You will get greater strength.

METHODS AND COST OF CONCRETE ROAD CONSTRUCTION IN MILWAUKEE COUNTY.

By H. J. Kuelling.*

Milwaukee commenced to build roads in 1912 and was at that time in considerable doubt as to which type of road to use. I was detailed to investigate bituminous concrete roads, and made a considerable study of this type of construction, finding that in a great many cities they had not had the success with this type of pavement that they had expected. Attention was then directed to the concrete road, and after considerable investigation, it was adopted as the type of proper pavement to be used.

We had considerable misfortune with the concrete road during the first year of its use. We attempted to keep the cost down by using local gravel. This was done after some investigations as to the suitability of this material, and later we attempted to add crushed stone to the gravel in an endeavor to secure proper proportions between the fine and coarse aggregate. This was an utter failure, and I believe that anyone who repeats the experiment will have the same results.

Our 1912 work was not a success, and nowhere near what we would have liked it to have been. About five or ten per cent of our pavement was an utter failure. This was covered during the past year with a bituminous top; we have protected it as well as we could and are getting considerable wear out of it. The bituminous treatment which we have given these concrete roads has not been a success; we used a light tar, went to considerable expense in cleaning the pavement, and did the best we knew to secure a proper bond, but the top peeled off quite extensively.

In 1913 we changed our methods in the construction of concrete roads. All material is now separated into fine and coarse aggregate, and in all but one road constructed during 1913, the material has been so washed as to remove practically all clay. This treatment of the material has increased the cost, since it necessitated

*County Highway Commissioner, Milwaukee, Wis.

shipping the material to all except one piece of work. The local material was not sufficiently good to justify its separation and washing, so we were obliged to ship it in from the outside. The material used last year was mostly glacial gravels which are shipped from 25 to 150 miles. In one piece of work we used about half crushed granite. We have not as yet used any crushed limestone. We do not consider limestone sufficiently hard to stand the abrasion, and we believe the additional expense in securing harder aggregate is justified. Our only change in the future will be to increase the percentage of crushed granite.

I am glad the preceding speaker brought out the question of sub-grades. At the present time we do not own a roller and there are many miles of our road that have not had the sub-grade compressed in any way. In six miles of road built in 1912 we had exceedingly few cracks. We built in 1913 about twenty-two miles of pavement, and I have yet to see the first crack. We are hauling a great deal of our material with heavy tractors, and have compacted a good deal of the sub-grades that way. Some of the sub-grade has not been compacted at all. That may have something to do with the absence of cracks and it may not; but, personally, I do not think it necessary to compact the sub-grade as much as some people would have us believe is necessary.

We call anything below one-quarter inch, sand, or small aggregate, and anything above one-quarter inch, stone or large aggregate. We have paid considerable attention to the percentage of voids in the sand and stone. I have a small laboratory in connection with the office and run a good many experiments on the local materials; it pays us to seek the sand and the stone that have the lowest percentage of voids. I do not adopt a specification blindly. A proportion of about $1:2:3\frac{1}{2}$ is what we try to use; but with a percentage of voids in the stone, sometimes as low as 40, we can very safely use a $1:2:4$ mixture; whereas if the voids were about 45% we would use a $1:2:3\frac{1}{2}$ mixture. The same argument holds in regard to the sand. I do not believe in blindly adopting any mixture. I want to find what quality we have and then act accordingly. That is, provided you ship from one pit in which the material is more or less graded uniformly.

A few words regarding the cement. We used one brand during 1913 and during 1914 we will use four brands. All cements

were tested at the mill and the tests were checked at the mill. We did not trust anybody in 1913. We did not have as we now have any chemical requirements.

In connection with the cement sacks we followed a plan that has produced results of which we feel more or less proud. We used between 300,000 and 400,000 bags of cement and lost between one and two per cent of the bags; but quite a large percentage of the loss was due to the use of the bags by the men for knee pads, or for aprons, etc.

We have all the cement delivered on the job whether the work is being done by ourselves or by contract, to avoid any chance of the contractor desiring to furnish the cement. Half of the 1913 work was done by contract, on the other half it was done under my direction. We require that the contractor and our foreman take good care of the sacks, bundle them immediately into bundles of fifty each and put a stamp on them with a tag having the name of the contractor or foreman, and the dealer delivering the cement; I had rubber stamps prepared beforehand and gave one to each foreman and had them stamp the bundle immediately after it was tied up, and delivered as soon as possible to those furnishing the cement, who were held responsible for the return of the sacks to the mill.

We are not satisfied with our practice in making joints. During the past year we have used what is called the armor-plate joint. During the coming season we are going to build considerable mileage without any protection plates,—about half our work with the protection plate and half without. We find that there are a good many pavements in this country in which no steel protection has been used, that are giving quite good results. We have placed our joints 35 feet apart; next year we are going to place them 50 feet apart. We have not experienced any cracking in the pavement and we are going to see what results we will have. I believe, with the former speaker, it is not a matter of expansion—it is a matter of contraction. We used one-fourth inch joints. In no case have I seen a slipping of the pavement at the joints, or anywhere else for that matter, excepting one place where two contracts joined; where one started where the other stopped. That may or may not be due to the heaving which occurred before the spring came.

We are not satisfied with any steel form in the market; they are heavy and if they get out of shape they are a total loss. We use a wooden form with an angle iron or channel iron protection on the top as a straight edge. We have in most cases placed loops on the sides to drive stakes through, to hold them to grade and to a certain extent, where from 100 to 150 feet of forms are set ahead, to maintain a uniform grade from station to station. We get a considerable amount of material ahead in order to keep the teams far from the men that are placing the concrete; the stone is placed on one side and the sand on the other. In some of the work, a foreman spreads the material wide enough to permit the cement teams delivering between the rows, and on other work, the teams deliver along the berm of the road. We do the grading as far ahead as we can, in order to give it a chance to settle naturally, and if we could, without the public complaining too much, we would let it settle through the winter; we tried this but did not meet with much success from a publicity point of view.

All the concrete on our own work is placed with a gravity spout, and not with a boom. If I were going to build a two-course pavement I would prefer the boom; for our one course work we use a spout. We are building the pavement 15 to 18 feet wide, 6 inches thick on the side and 8 in the middle. This is giving us a flat sub-grade with about 2 inches crown on either a 16 or 18 foot road. The concrete is placed and struck off with a form, and is finished as soon as possible by hand with a wood float. A mortar that is more or less stiff, one that will give a little rougher finish, and not work too much to the top is preferred; the less work the finisher does, the better I like it. I do not like too wet a concrete. I prefer the stiffest consistency that can be used and easily handled.

In curing, we use canvas if it is exceedingly hot; but I am more afraid of a windy day than I am a hot day. If it is very windy and even only 80 degrees temperature, we cover with canvas and if it is hot and windy, we cover much more quickly than if it is hot and not windy. The canvas remains until the pavement will stand the pressure of the earth; then we cover with one or two inches of earth from along the road and keep it sprinkled about five days. We keep people from the road if possible, although sometimes it is not possible unless you use a shotgun. We

remove the earth after twenty days and open the road to the public.

We have in the past season used in most cases a macadam or gravel shoulder. During 1914 we are not going to do that on roads 18 feet wide; we are going to build without a shoulder except near the city where there is considerable traffic along the road; in the country we are going to use an earth shoulder, because we find that the earth shoulders we made in 1912 are in as good condition as one would wish—the grass is growing in them, and we see no need for gravel shoulders.

We do not intend following the plan of putting bituminous treatment on our 1913 work, because we do not feel that we need it.

During 1914 we aim to get all my work finished by the first of October. We like to give all our work practically a month of wear before it is subjected to frost action, in order to give it as much time as possible to harden.

DISCUSSION.

Mr. Ferguson. MR. L. R. FERGUSON.—What is the material composing the sub-grade?

Mr. Kuelling. MR. H. J. KUELLING.—The sub-grade is sand in one or two cases and in the other cases quite a heavy and fairly uniform clay, not a sticky red clay. In a few cases we encountered springs and we had to use tile drain.

Mr. Wilson. MR. PERCY H. WILSON.—I would like to ask Mr. Kuelling if the road is built on a pretty heavy longitudinal grade or is the road flat?

Mr. Kuelling. MR. KUELLING.—The heaviest grade we have is six per cent, and that was built in 1913. The work in 1912 was not on very heavy grades, but we have several grades running from three to six per cent in our 1913 work. We have had little complaint within the past three or four weeks due to slippage. During the summer we carried on some experiments with an automobile and found it was impossible for it to slip. I have had no complaints at all from people driving automobiles,—the complaints were from people driving horses.

Mr. Smith. MR. B. S. SMITH.—I would like to ask Mr. Kuelling if he will go into the cost of the road, divide it into labor and material.

Mr. Kuelling. MR. KUELLING.—It is somewhat difficult to state the cost. The local conditions in rural work vary very largely in regard to the hauling, which is a very important item. I will divide the cost for one road that was exactly a mile long, 5200 and a fraction feet. It contained 10,510 square yards of pavement,—not quite a mile of 18-foot road; the gravel and sand delivered at the station, cost us $2889 or 27½ cents per square yard of pavement. The cost of the shoulders—we used the macadam from the old road—was about three and a half cents per square yard; the hauling and labor, that is unloading from the cars and hauling to the job, was a trifle over 27 cents per square yard; the cement

cost about $1.65 or thereabouts delivered on the work, or practically 42 cents per square yard, figured on the basis of about $1\frac{3}{4}$ barrels per cubic yard of concrete, and figuring a cubic yard as making five yards of pavement; the labor of laying concrete cost about $18\frac{3}{4}$ cents per square yard; sundries, such as expense of foremen, telephone and various other small items were about one cent per square yard; the material for the joints, placed 35 feet apart, cost $3\frac{1}{3}$ cents for the steel and $\frac{3}{4}$ of a cent for the felt per square yard; to these items I have added two others, one known as our compensation; we have a workmen's compensation act, and the loss due to that I have distributed over my entire season's work,—for this road it was about 3 cents per square yard; we had some misfortune, one or two men were killed, and this cost us about $600, which we distributed over our season's work; the other, the machinery depreciation distributed over all the work cost in addition 3 cents per square yard. The total cost was 1.30\frac{1}{3}$ per square yard of pavement for a trifle over a mile of road. Mr. Kuelling.

Now that is as fair an estimate as I can give you on the cost, and it happens to be almost the lowest one. Our work was built half by contract and half by day labor. The average cost, including everything, of the contract work, was almost identically the same as that done by day labor, and ran about $1.54 and a fraction per square yard, including inspection cost, excepting overhead and the engineer's charges, which is not added in.

MR. T. H. SKINNER.—Mr. Kuelling, what is the shape of the concrete slab where it comes against the shoulders; has it a perfectly square edge, or do you bullnose it? Mr. Skinner.

MR. KUELLING.—We have beveled them a slight amount, but I believe that on a narrow pavement it is a waste of money, because you are cutting off from four to six inches of the width of your pavement and not gaining anything. Very few vehicles get out on the shoulder of a road 16 or 18 feet wide, and I would rather go to the additional expense of running a road drag over the shoulders from time to time, than to waste five or six inches of the width of the pavement. Mr. Kuelling.

MR. SKINNER.—It seems to me that if the edge was bullnosed sufficiently it would obviate the necessity for the shoulder. My experience has been that it is impossible for a heavy team or an Mr. Skinner.

Mr. Skinner. automobile to get back on the road if the edge is square. Where it is beveled or bullnosed it is possible to get back; as many country roads are pretty soft on the shoulder, and vehicles occasionally do get off, the rounding of the edge of it would materially assist automobiles as well as teams in getting back on the road, and it would also avoid the necessity for a macadam shoulder.

Mr. Kuelling. MR. KUELLING.—We find that the shoulders after the first year are well backed, and we have no trouble in getting from the shoulder on to the concrete. We have no trouble after the first fall and spring. We have had no complaints whatever with our 1912 work, which has all earth shoulders.

Mr. Larned. MR. E. S. LARNED.—Mr. Kuelling's practice of omitting shoulders on pavements 18 feet wide is very good. A pavement of that width will admit of vehicles passing at considerable speed, and it is safer; the cost of the shoulders adds very materially to the cost of improved roads.

I would like to ask Mr. Kuelling what his practice is with regard to the wetting of sub-grades?

Mr. Kuelling. MR. KUELLING.—The weakest part of our method of construction was that we did not wet the sub-grade enough. Although as yet there are no bad results, we find that the concrete, if it is the least bit wet, will run ahead of where you are working, and wet the sub-grade. In some cases we have wet the pavement and if you have a considerable amount of material ahead, sand and stone, that will hold the moisture in the sub-grade. We spread almost over the entire length of a 16 or 18-foot road, and as the rains fall they seep through and keep the sub-grade wet. We very seldom had a dry sub-grade.

Mr. Boynton. MR. C. W. BOYNTON.—I want to protest a little on the practice of making your concrete so wet that the excess water will run out and keep the sub-grade properly wet. I think when the sub-grade is too wet there is great danger and I hope that Mr. Kuelling's practice will not become general.

Mr. Kuelling. MR. KUELLING.—I believe I made the statement that I did not like a thin consistency, but you cannot help the water running out that is bound to moisten your sub-grade; you add more water before you are through. I don't want any water running away from concrete on the sub-grade, that is the last thing I want. I don't want to see the water running from the top o

my pavement and out under the shoulder, because we consider that a big loss. Mr. Kuelling.

MR. STUBBS.—I want to say that I endorse Mr. Boynton's position that concrete used in a road should not have excess water to wet the sub-grade. If the sub-grade is too dry there is shrinkage in the sub-base. Why not provide for that by some other method. Mr. Kuelling has done well in Milwaukee County in not rolling his sub-grade; if it is not rolled too much it will not be necessary to wet the sub-grade to hold the moisture. You ought to wet the sub-grade a little but it is not necessary to use much water. Mr. Stubbs.

MR. WILSON.—I would like to ask Mr. Kuelling if he does not think that the fact that he has had good results in not rolling his sub-grade depends to a certain extent on the fact that he is building his road in a rolling country, where he naturally has good drainage. If the road was laid in a flat country, certainly with an unrolled sub-grade his pavement would heave and crack. Mr. Wilson.

MR. KUELLING.—The worst heaving we have in Wisconsin is on the hillside. The underground water comes out in the form of springs, and tile drain has been used in roads built on hillsides but not on the flats. The most trouble we have had seems to be on hillsides rather than in the flats where no heaving has been observed. Mr. Kuelling.

MR. LARNED.—I would like to add just a word on the question of consistency, because that is something I have been speaking about quite a good many years. I do not think I misunderstood Mr. Kuelling in what he had to say about consistency. I am in hearty accord with that. I understood him to favor the plastic mixture, not a mixture with surplus water. This consistency can be obtained with thorough mixing with less water and it is a pretty difficult matter to describe it, but it does not have any free water to run out of it until you begin to compact it or press it. As it lies at rest on the road it is a plastic mass that rolls and does not flow; a concrete of that consistency will be very largely free from laitance, and will offer a much better mechancical bond for a bituminous binder. Mr. Larned.

In connection with bituminous coverings I believe that better results can be obtained if they are not put on too soon. Put the pavement into service, let it age a little, let it get as far

Mr. Larned. through its early shrinkage process as possible before you put the binder on; and if you do that, a slight wear to the surface will produce a roughness that will offer better mechanical bond for the bituminous binder. This, of course, necessitates thorough cleaning of the pavement; that can be done, not with brooms, however, but with water or with air.

Mr. Kuelling. MR. KUELLING.—I might add a word for consistency,—a little, simple test that I have. Give the batch of concrete such a sweeping stroke with a shovel that you bring enough mortar to your surface to finish it. You can smooth it down with the shovel at one stroke to about the consistency you want without exposing the aggregate.

In regard to putting on a bituminous top, I agree with the last speaker, that it is necessary to wash the pavement. We tried very carefully with our pavement—it was six or eight months old—and swept first with a steel broom, then a corn broom, and we did the best we could to clean it, but it was not a success. Now we are trying to take a very light broom at first and then follow that with the asphalt, and I believe we are getting better results.

The President. PRESIDENT HUMPHREY.—The thorough mixing referred to by Mr. Larned means keeping the material in the mixer and revolving it much longer than is usually the case, which is generally not over one-half minute. It should be longer than a minute and a half to secure the proper consistency. The use of smaller aggregates also produces a better consistency. The use of one and one-half inch stone may seem desirable but it does not produce the consistency that the smaller aggregates does, and the latter enables one to secure a plane surface with a minimum of effort. The time is coming when the materials of concrete will be kept in the mixer about two minutes and very little water will be used; this longer time of mixing will be more than compensated for by the resulting increase in the durability of the pavement and the greater ease with which it can be finished.

Mr. Cline. MR. A. E. CLINE.—I would like to add just a word in regard to consistency, from an experience that I had a couple of years ago in making concrete hollow tile. We mixed the concrete and then ran it into an agitator; we found we got the best results when it was agitated from a half to three-quarters of an hour.

We were using three-eighths stone down to dust, and about 1 to 5 mixture; we tried to stir that by hand method and make it wet enough to bed the tile; as soon as you stopped stirring, it settled and water came to the top. This mixture after it had been agitated half to three-quarters of an hour would stand in a pile and never settle. While this may be too long a time to mix for practical work, it simply illustrates the advantage of more thorough mixing to prevent separation. Mr. Cline.

MR. LARNED.—In the experience of men making cast stone it is frequently found that they have to have an aggregate so graded that it will make a composition that results in what they call standing up, supporting itself. There is no actual segregation in the resultant mixture. They have had a great deal of trouble at times by using a certain kind of aggregate that will not stand up, and they get an uneven texture; but where a combination of aggregates produces that quality, and that it is largely by the reduction of voids, the material does stand up better. This is of prime importance in road construction. Following that thought—this is purely deduction—it occurs to me that broken stone will stand up better in mortar than gravel by reason of its rough surface and its angular form. I think the round stone is more apt to settle in mortar than broken stone. It is quite essential that coarse hard aggregate should be as near the surface of the road as possible; and that again emphasizes the necessity of having a plastic and stiffer mix, because then your mortar is of a consistency that will support the aggregate and keep it near the surface. If it is too thin your coarse stone go to the bottom and your fine stone come to the top, and that is just reversing the required composition of your road surface. Mr. Larned.

MR. ALLEN BRETT.—Has Mr. Kuelling used hydrated lime and does he favor its use? Mr. Brett.

MR. KUELLING.—I have never had experience with it in any form. Mr. Kuelling.

MR. P. H. ATWOOD.—I would like to know whether it makes any difference whether the water is added when you first start mixing, or whether the material is first mixed dry. Mr. Atwood.

MR. KUELLING.—I find that it is pretty hard to get the workmen to carry that out. The inside of your drum is damp and the Mr. Kuelling.

Mr. Kuelling. dry cement sticks to the sides; we add the water as soon as the materials are in the drum.

Mr. Larned. MR. LARNED.—I would like to ask if he scores the pavement in any way or leaves it with the wood float surface.

Mr. Kuelling. MR. KUELLING.—In all cases but one we left it with a wood float finish; in that case we followed up with a broom. I do not believe it is worth the trouble; scorings wear out rather quickly and you don't get much benefit from them. In Kansas City, where they have built a good deal of concrete pavement, they finish it with the shovels, and this leaves a comparatively smooth finish, which tends to wear smoother.

Mr. Larned. MR. LARNED.—I have had an occasion this past year to observe a concrete pavement that has been scored very much like paving blocks, and I was very much surprised to find the excellent wear of those markings along the joint lines. Those joints are beveled; they are not built square. It occurs to me that possibly if the armor joint was omitted it might be just as well to give the edge a slight bevel. If cement is built with a sharp edge it is more apt to suffer than if it is rounded.

Mr. Boynton. MR. BOYNTON.—Mr. President, in my opinion the grooves in a concrete pavement are unnecessary and particularly bad. It is apparent from an observation of such pavements that the wear is very much more rapid at the grooves than elsewhere. The pavement between Randolph and Lake Streets, Chicago, along the side of the American Steel and Wire Company's warehouse, was laid eleven years ago and has been subjected to excessively heavy traffic during all this time. This pavement was originally grooved but fortunately not to a very great depth; however, the wear on the pavement was much more rapid until the grooved surface was gone than it has been since. The only argument in favor of grooving is to give a better foothold for horses. It is a fact, however, that concrete pavements not grooved are not slippery and the concrete pavement above referred to, where the grooves are entirely obliterated, has never become slippery.

In addition to accelerating the rate of wear, grooving the surface of a concrete pavement materially increases the cost of construction and greatly increases the noise of traffic. In some pavements the additional cost of a grooved or corrugated surface,

as compared with a smooth, wood float finish, has amounted to as much as ten cents per square yard. Mr. Boynton.

MR. LARNED.—I do not want to appear on the record as favoring the scored pavement. I have disclaimed any such belief too many times to be identified with the practice. I am suggesting the scored treatment of a joint if the armor is omitted. Mr. Larned.

PRESIDENT HUMPHREY.—The Chairman believes that the present use of the steel plate to protect the joints is an wholly unnecessary expense. The time is coming when the use of felt without metal protection plates will be found by experience to be the best practice. Furthermore he does not believe that these thick joints are necessary; a single or at best a double thick felt is all that is necessary. The felt should extend through the pavement and about one inch above its top surface. The brooming of this projecting felt serves as a protection for the joint. This is the practice in Europe, where pavements have been in successful use for more than ten years. A first-class roadway should have a perfectly smooth surface in which there is no material that will wear unequally and produce ridges or high spots which result in rutting in the pavement from the impact of the passing vehicles. The President.

MR. LARNED.—I am a great believer in an accurate surface. This necessitates an accurate grinding of the materials and a very careful float finish. I think the inequalities of the surface of any pavement are more responsible for its rapid wear than any other cause. I believe that an inferior material, if accurately surfaced and kept accurate, will wear longer than a considerably better material if poorly surfaced. Every little depression in the pavement serves to accentuate the blow of the wheel when it drops into it. I believe, further, that the time is not far off when we will have to attempt, by legislation, perhaps, some regulation of traffic which will determine the width of the tire, the diameter of the wheel and possibly also the speed of the vehicle. We are very reckless in this country in the use of any public convenience. Anything that the public provides is abused. We will have to find some way of preventing this, conserving our pavements in some way, and I think possibly it may be by legislation. Mr. Larned.

MR. KUELLING.—We are up against the same difficulty in our state and last summer we passed a resolution requesting our Mr. Kuelling.

Mr. Kuelling. next legislature to regulate the width of tires in proportion to the loads.

Regarding workmanship on the pavement, I believe that where there are depressions in the pavement that hold moisture, the pavement is going to wear faster at these places than anywhere else. I believe that a pavement that is more or less wet will have more abrasion than one that is dry.

THE EXPANSION AND CONTRACTION OF CONCRETE ROADS.

By R. J. Wig* and W. S. Gefvert.†

The Bureau of Standards in connection with a general investigation of the volumetric changes which take place in concrete structures due to change in atmospheric temperature and moisture conditions made a number of measurements on concrete roads near New Village, N. J., and Nazareth, Pa., with the assistance and co-operation of W. A. McIntyre, Road Engineer, Association of American Portland Cement Manufacturers.

These measurements were made by stretching an invar tape, graduated to meters (with the millimeters indicated for a distance of one centimeter each side of the meter mark), along the road, spanning several slabs and reading the tape at every second meter, with reference to a mark on a brass or glass plug which was previously set into the concrete. The measurements reported in this paper were made on a concrete road on Morris Turnpike, near New Village, N. J., for a period from October, 1912, to October, 1913, and on a road at Nazareth, Pa., from June to October, 1913.

The results of these measurements are given diagrammatically in Fig. 1, 2 and 3 in which the linear changes occurring in a number of slabs have been plotted together with curves showing the mean temperature, moisture and weather condition. The figures recorded as slab changes represent changes between the points nearest the ends of the slabs. Readings were recorded to hundredths of a millimeter (0.00039 inches).

Referring to these diagrams it is noted in Fig. 1 that slabs a, c, e, f, g, h, o, and q, or the majority of them, show their maximum expansion in April or previous, and with one or two exceptions all slabs showed a marked contraction during August when the temperature was highest. The slabs shown in Fig. 2 show somewhat the same results as those of Fig. 1. The measurements of

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slab z_3, Fig. 2, were started five days after the concrete was laid. The slab shows an elongation from November to April, when it reaches a maximum, followed by a shortening until August, when a decided shortening is evidenced and this is followed by an elongation until October. During this period there was a mean temperature range of 84 deg. Fahr. Since measurements were not started at Nazareth, Pa., until June the concrete was not exposed to a large amount of moisture during the first month, and yet in the majority of cases it will be observed, referring to Fig. 3, that the slabs showed an expansion during the first few weeks which would appear to be due to rise in temperature, but practically all slabs showed a marked contraction during July and August, when the temperature was highest and the effective rainfall least.

Slab k, Fig. 3, shows a continual shortening of a 32-ft. slab. The concrete was placed June 9 and measurements started June 18. Between the latter date and August 19 there is a considerable shortening of the slab, although the temperature had increased during this period. From August 19 to September 30 there was a drop in temperature and the shortening still continued. The only explanation which can be given for the marked contraction in slab k, Fig. 3, is that this slab was constructed on an old concrete road in which the cracks were sealed with cement mortar and a half inch layer of clay placed upon this base to prevent bond being formed between the new and old concrete. These conditions prevented the new concrete from absorbing moisture from below, thus, a rich mixture being used there was probably only slight absorption from the top and consequently continual drying would cause a shortening of the slab.

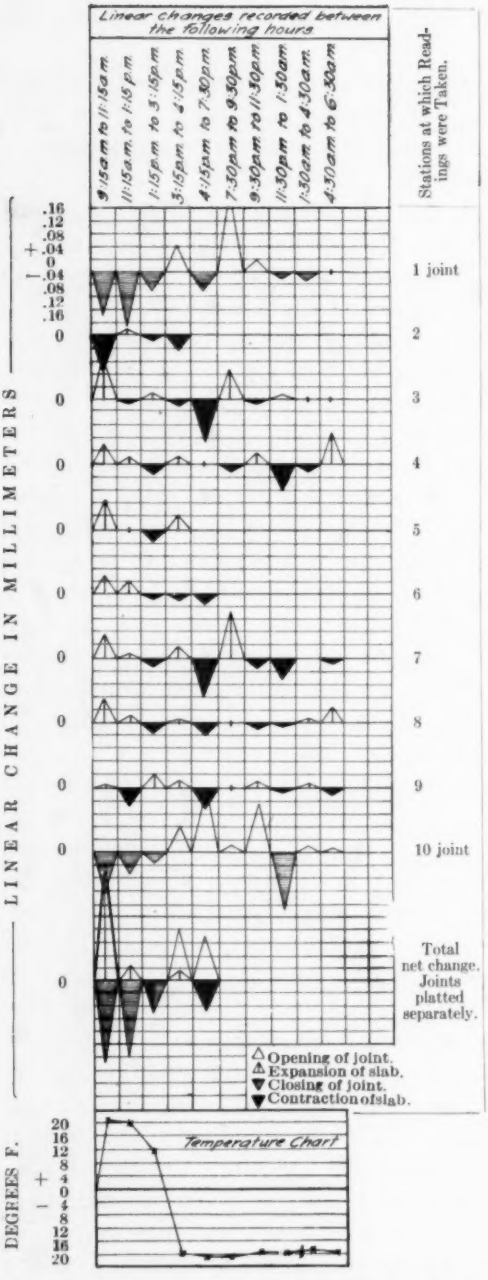
Slab e, Fig. 1, was observed over the same period as slab z_3, Fig. 2. Measurements were started on slab e the day after the concrete was laid. During the winter months there is indicated an increase in length, and from April until August a decrease. Slab z_3, Fig. 2, shows the same movements as slab "e," excepting during the first week. From August until October both of these slabs showed a continued expansion, which can only be explained by the increase in moisture content, as the temperature decreased materially during this period and should have caused a contraction in the slabs.

Slabs a to e of Fig. 1 showed rather erratic movements the

first week for which no explanation can be offered, other than that these slabs were sprinkled more thoroughly than any of the other slabs and that the expansion might be due to rise in temperature brought about by chemical action during setting.

As previously stated, the changes plotted do not represent the differences obtained from observations made only upon the end reference plugs of each slab, but are obtained by summing up the changes observed at points two meters apart throughout the length of the slab. A series of these observations made upon a number of slabs of Course C are given in Fig. 4. It is of interest to note that in every slab there appears to be a reversal of movement, that is, if considerable expansion occurred through the central portion of the slab the end sections showed contraction which probably resulted from frictional restraint on the sub-base. Where the central portion of the slab shows contraction the end sections show expansion, which also would appear to be caused by the frictional resistance or drag on the sub-base. Comparing the movement in the concrete for different periods with the temperature change for the same periods it is found that the greater expansion occurred during the months of greatest precipitation, and lower temperature and the greater contraction during the periods of highest temperatures and low precipitation.

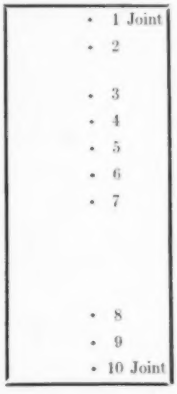
In Fig. 5 is shown the linear changes observed over a period of 21 hours on sections of a slab of Course J, Morris Turnpike, near New Village, N. J. These observations show that there is a constant movement in the concrete of considerable magnitude. It is regretted that observations were not made continuously over the entire length of slab. A strain gauge was used in making these readings. It is interesting to note that the movement is not uniform throughout the slab, and while certain sections show expansion others show contraction, which accords with our previous observations. The concrete shows expansion with a rise in temperature, but it should be observed that although the temperature started to fall at 1 P. M. and fell 40 deg. by 4 P. M., where it remained practically constant until the following morning at 6 A.M., the concrete continued to show considerable expansion until 9 P.M., or, in other words, there appeared to be a lag in the movement of the concrete of 8 hours or more behind the temperature change at the surface.



Concrete laid Nov. 8, 1912 Observations made Nov. 25 and 26 1913. Construction of road—Mixture concrete 1 : 2 : 4. Cement used Brand Ve. Width 16 ft. Thickness 6 in. Surface finished with template and wooden float. Covered with dirt and sprinkled daily for 7 days. Grade 5.13 per cent slope. Stone drain on north side of road.

Gage length = 50 cm. (19.7 in.).
1 millimeter = 0.03937 in.

Diagram of slab showing location of reference plugs.



LINEAR CHANGES OBSERVED OVER A PERIOD OF 21 HOURS ON COURSE "J" MORRIS TURNPIKE NEAR NEW VILLAGE, N. J.
RESULTS OF INVESTIGATIONS BY BUREAU OF STANDARDS.
FIGURE 5.

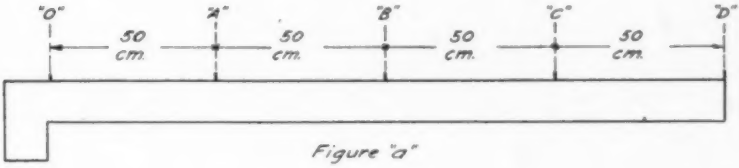


Figure "a"

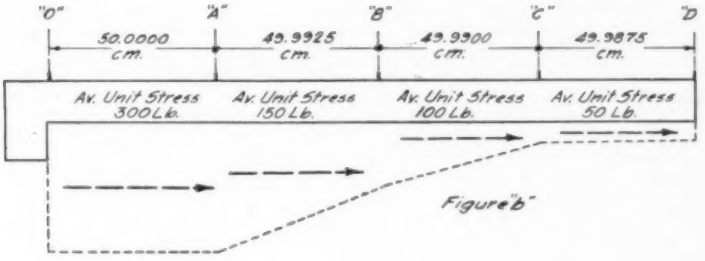


Figure "b"

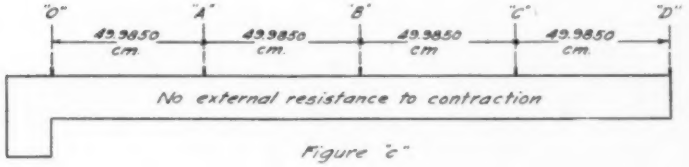


Figure "c"

SPACE.	FIGURE "a."	FIGURE "b."	FIGURE "c."
OA	50.0000	50.0000	49.9850
OB	100.0000	99.9925	99.9710
OC	150.0000	149.9825	149.9550
OD	200.0000	199.9700	199.9400
AB	50.0000	49.9925	49.9850
AC	100.0000	99.9825	99.9710
AD	150.0000	149.9700	149.9500
BC	50.0000	49.9900	49.9850
BD	100.0000	99.9775	99.9710
CD	50.0000	49.9875	49.9850

Modulus of Elasticity = 1,000,000. Coefficient of Expansion = .000006.
Temperature drop = 50 deg. F.

Making the above assumptions and referring to Fig. "*b*"—with "*O*" as a fixed point the contraction in the slab resulting from a lowering of the temperature 50 deg. F. tends to draw the points "*A*," "*B*," "*C*" and "*D*" towards point "*O*." This action is opposed partially by friction on the base of the slab which varies in the different sections and results in varying unit stresses (tension) in these different sections.

Friction on section OA neutralizes the unit stress of 300 lbs. in the section and there is no movement of point "*A*."

After the completion of the movement caused by the temperature drop, the resulting average tensile stresses acting in sections AB, BC and CD are assumed to be respectively 150, 100 and 50 lbs., which prevent complete contraction in these sections, and based on these assumptions the values in the above table have been calculated.

EFFECT OF FRICTION ON LINEAR CONTRACTION.

RESULTS OF INVESTIGATIONS BY THE BUREAU OF STANDARDS.

FIGURE 6.

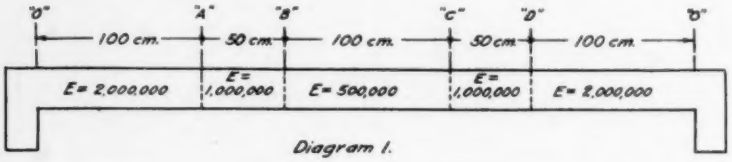


Diagram 1.

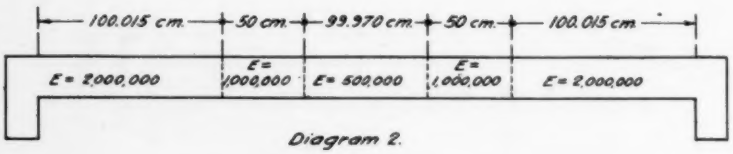


Diagram 2.

SECTION.	DIAGRAM 1.	DIAGRAM 3.	MAX. VARIATION.
O-A	100.000	100.015	+ .015
O-B	150.000	150.015	+ .015
O-C	250.000	249.985	− .015
O-D	300.000	299.985	− .015
O-O	400.000	400.000	000
A-B	50.000	50.000	000
A-C	150.000	149.970	− .030
A-D	200.000	199.970	− .030
A-O	300.000	299.985	− .015
B-C	100.000	99.970	− .030
B-D	150.000	149.970	− .030
B-O	250.000	249.985	− .015
C-D	50.000	50.000	000
C-O	150.000	150.015	+ .015
D-O	100.000	100.015	+ .015

Assumptions.—Modulus of Elasticity for concrete as indicated above Temperature increase of 50 deg. F.

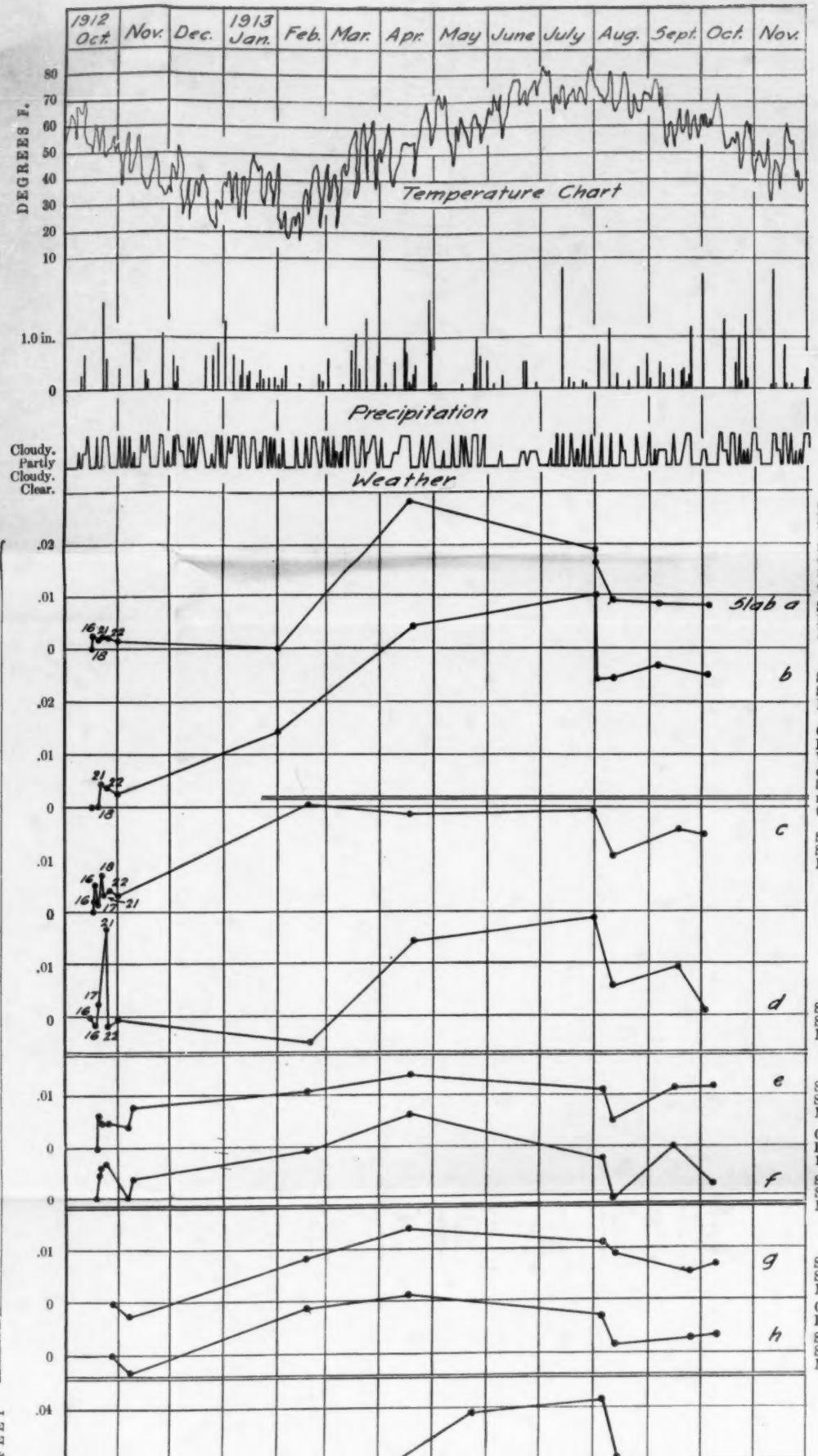
Coefficient of expansion for concrete = .000006.

Points "*O*" in the above diagrams are fixed. Diagrams 1 and 2 show the relative positions of points "*A*," "*B*," "*C*" and "*D*" before and after an assumed increase in temperature of 50 deg. F. Since the ends are fixed, the slab cannot elongate and there is a uniform compressive stress throughout the concrete. Since the moduli of the various sections are not equal, there is a re-adjustment of lengths as shown in Diagram 2, which represents conditions after the increase in temperature when equilibrium has been reached.

EFFECT OF TEMPERATURE CHANGE IN SLAB WITH FIXED ENDS MADE UP OF SECTIONS WITH UNEQUAL MODULI OF ELASTICITY.

RESULTS OF INVESTIGATIONS BY THE BUREAU OF STANDARDS.

FIGURE 7.



Course A. Morris Turnpike, near New Village, N. J.
Brand of cement, A; Brand of sand, Hodson; Mixture, 1 : 1½ : 3½; Width, 14 ft.; Thickness, 6 in.; Character of sub-base, 12 in. stone, rolled with 10-ton 3-wheeled roller. Placed Oct. 11, 1912. Tile drain on north side of road. Surface finished with template but neither troweled nor broomed. Concrete surface kept wet for seven days, not covered with dirt. Bituminous carpet covering.

Slab a.
Length, 78 ft.
Measured Length, 75.5 ft.

Slab b.
Slab Length, 52 ft.
Measured Length, 49.2 ft.

Course B. Morris Turnpike, near New Village, N. J.
Brand of cement, B; Brand of sand, Hodson; Mixture, 1 : 1½ : 3½; Width, 14 ft.; Thickness, 6 in.; Character of sub-base, Old Macadam, scarified and reshaped, but old crown not entirely removed. Sides brought up somewhat with new 1½ in. stone. Tile drain on north side of road. Placed Oct. 15, 1912. Surface finished with template and wooden float and broomed. Concrete surface kept wet for seven days, not covered with dirt. Bituminous carpet covering.

Slab e.
Slab Length, 50 ft.
Measured Length, 46 ft.

Slab d.
Slab Length, 57 ft.
Measured Length, 55.8 ft.

Slab e.
Slab Length, 44 ft.
Measured Length, 39.4 ft.

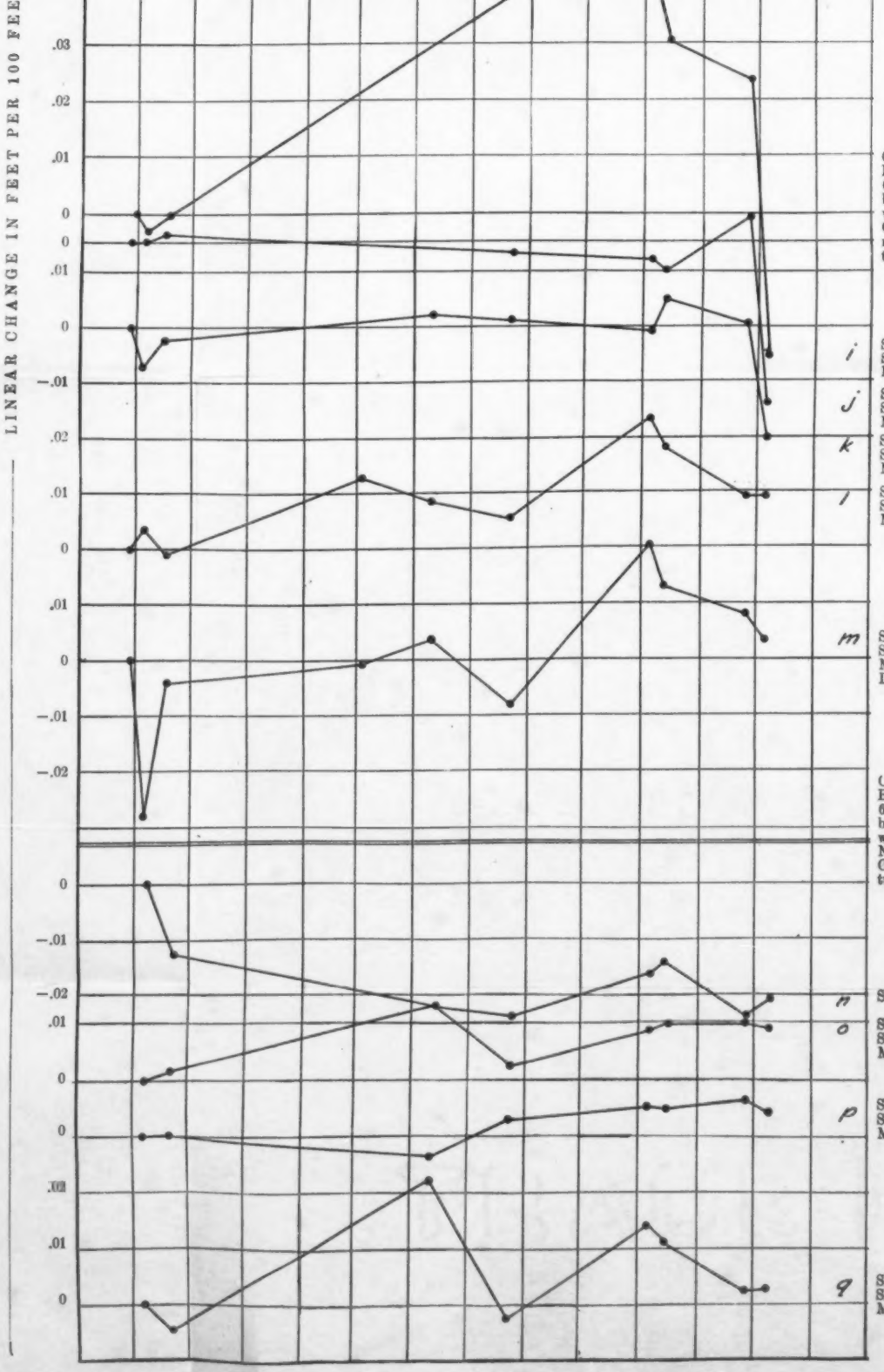
Course C. Morris Turnpike, near New Village, N. J.
Brands of cement, B and C; Brand of sand, Hodson; Mixture, 1 : 1½–3½; Width, 14 ft.; Thickness, 6 in.; Character of sub-base, Old Macadam, scarified and reshaped, but old crown not entirely removed. Sides brought up somewhat with new 1½ in. stone. Tile drain on north side of road. Placed Oct. 16, 1912. Surface finished with template and wooden float and broomed. Concrete surface kept wet for seven days, not covered with dirt. Bituminous carpet covering.

Slab f.
Slab Length, 70 ft.
Measured Length, 59 ft.

Slab g.
Slab Length, 50 ft.
Measured Length, 42.7 ft.

Course D. Morris Turnpike, near New Village, N. J.
Brand of cement, B; Brand of sand, Baker; Mixture, 1 : 1½ : 3½; Width, 14 ft.; Thickness, 6 in.; Character of sub-base, Old Macadam, scarified and reshaped, but old crown not entirely removed. Sides brought up somewhat with new 1½ in. stone. Tile drain on north side of road. Placed Oct. 18, 1912. Surface finished with template and wooden float and broomed. Concrete surface kept wet for seven days,

Slab h.
Slab Length, 49 ft.
Measured Length, 46 ft.



Surface finished with template and wooden float and broomed. Concrete surface kept wet for seven days, not covered with dirt. Bituminous carpet covering.

Course E. Morris Turnpike, near New Village, N. J. Brand of cement, A; Mixture, 1 : 2 : 4; Width, 16 ft.; Thickness, 6 in.; Character of sub-base, Old Macadam, scarified and reshaped, but old crown not entirely removed. Sides brought up somewhat with new 1½ in. stone. Tile drain on north side of road. Placed Oct. 28, 1912. Surface finished with template and wooden float not broomed. Concrete surface neither covered nor wet. Longitudinal cracks in slabs i to k.

Slab i.
Slab Length, 30 ft.
Measured Length, 19.7 ft.

Slab j.
Slab Length, 30 ft.
Measured Length, 26.3 ft.

Slab k.
Slab Length, 26 ft.
Measured Length, 19.7 ft.

Slab l.
Slab Length, 23 ft.
Measured Length, 13.1 ft.

Slab m.
Slab Length, 25 ft.
Measured Length, 16.4 ft.
Diagonal crack.

Course F. Morris Turnpike, near New Village, N. J. Brand of cement, B; Mixture, 1 : 2 : 4; Width, 16 ft.; Thickness, 6 in.; Character of sub-base, Old Macadam, scarified and reshaped, but old crown not entirely removed. Sides brought up somewhat with new 1½ in. stone. Stone drain on north side of road. Placed Nov. 5, 1912. Surface finished with template and wooden float. Concrete surface covered with dirt and wet for seven days. Longitudinal cracks in slabs n and o.

Slab n. Slab Length, 23 ft. Measured Length, 23 ft.

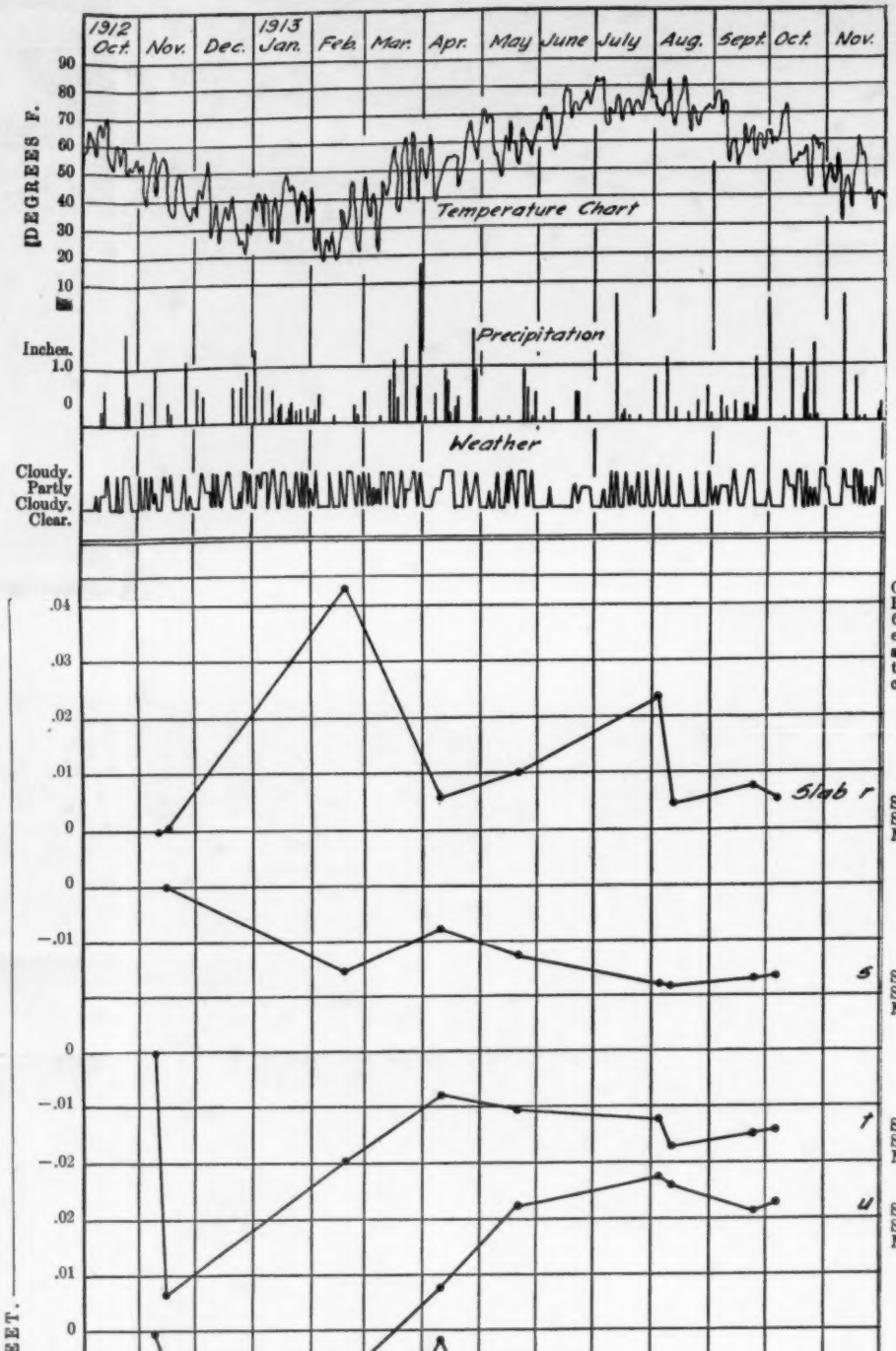
Slab o.
Slab Length, 30 ft.
Measured Length, 19.7 ft.

Slab p.
Slab Length, 31 ft.
Measured Length, 26.2 ft.

Slab q.
Slab Length, 29 ft.
Measured Length, 26.2 ft.

PLATE I.
PROCEEDINGS AMERICAN CONCRETE INSTITUTE.
VOL. X.
WIG AND GEFVERT
ON
THE CONTRACTION AND EXPANSION
OF
CONCRETE ROADS.

RESULTS OF MEASUREMENTS OF LINEAR CHANGES IN CONCRETE SLABS IN A CONCRETE ROAD ON MORRIS TURNPIKE, NEAR NEW VILLAGE, N. J.
OBSERVATIONS COVER 1 YEAR FROM OCTOBER, 1912.
RESULTS OF INVESTIGATIONS BY BUREAU OF STANDARDS.
FIGURE 1.



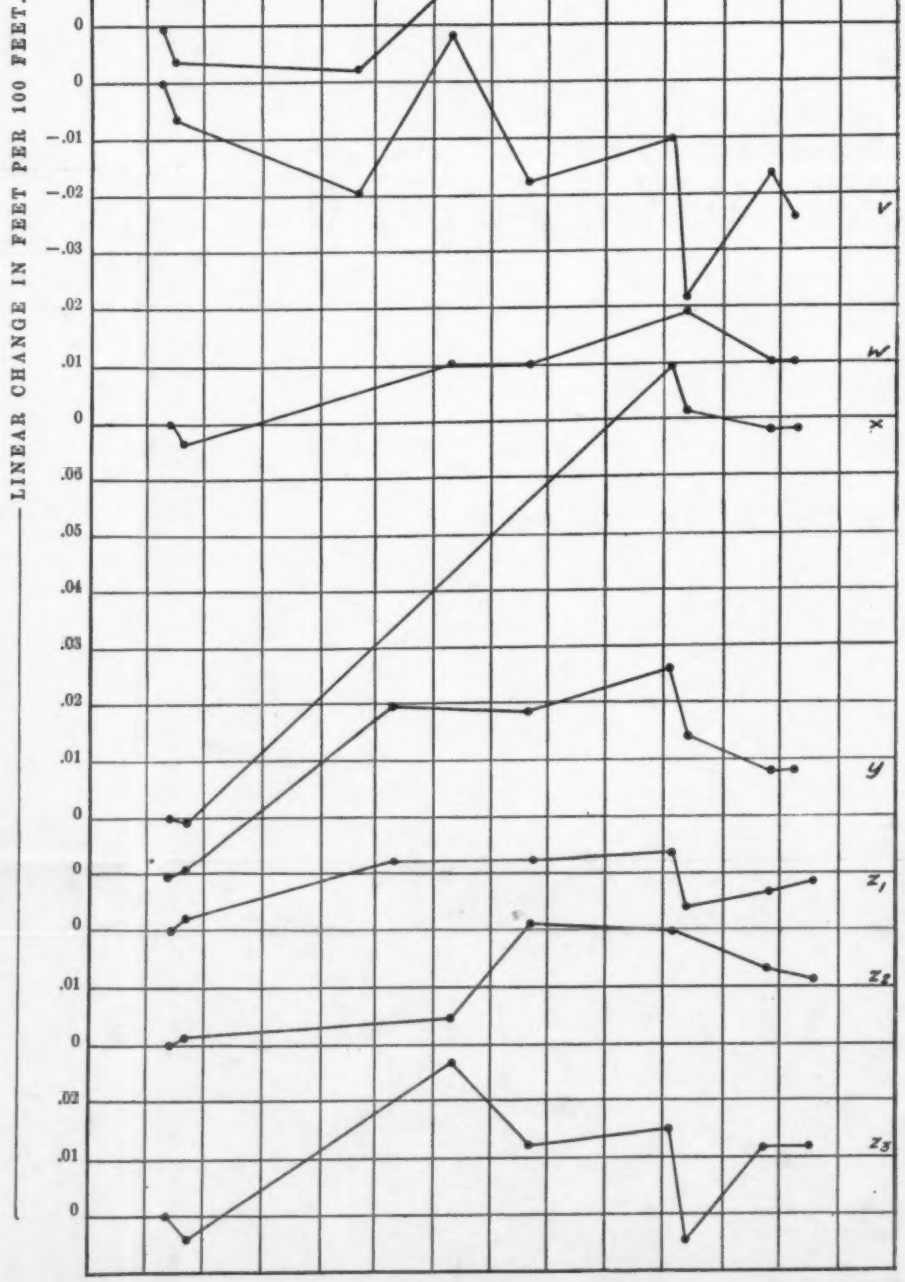
Course G. Morris Turnpike, near New Village, N. J. Brand of cement, A; Mixture, 1:2:4; Width, 16 ft.; Thickness, 6 in.; Sub-base, Old Macadam scarified and reshaped, old crown not entirely removed. Sides brought up somewhat with new 1¼-in. stone. Tile drain on north side of road. Surface finished with template and wooden float, not broomed. Surface of concrete covered with dirt but not wet. Concrete placed Oct. 26, 1912.

Slab r.
Slab Length, 23 ft.
Measured Length, 12.1 ft.

Slab s.
Slab Length, 25 ft.
Measured Length, 19.7 ft.

Slab t.
Slab Length, 24 ft.
Measured Length, 19.7 ft.

Slab u.
Slab Length, 25 ft,
Measured Length, 12.1 ft.



Slab v.
Slab Length, 25 ft.
Measured Length, 23 ft.

Course H. Morris Turnpike, near New Village, N. J.
Brand of cement, B; Mixture, 1:2:4; Width, 16 ft.; Thickness 6 in.; Sub-base, Old Macadam scarified and reshaped, old crown not entirely removed. Sides brought up somewhat with new 1½-in. stone. Stone drain on north side of road. Concrete placed Nov. 8, 1912. Surface finished with template and wooden float, and broomed. Surface of concrete covered with dirt and wet for seven days.

Slab w.
Slab Length, 30 ft.
Measured Length, 26.2 ft.

Slab x.
Slab Length, 28 ft.
Measured Length, 19.7 ft.

Slab y.
Slab Length, 30 ft.
Measured Length, 26.2 ft.

Course J. Morris Turnpike, near New Village, N. J.
Brand of cement, B; Mixture, 1:2:4; Width, 16 ft.; Thickness, 6 in.; Sub-base, Old Macadam scarified and reshaped, old crown not entirely removed. Sides brought up somewhat with new 1½-in. stone. Stone drain on north side of road. Concrete placed Nov 8, 1912. Surface finished with template and wooden float. Surface of concrete covered with dirt, and wet for seven days.

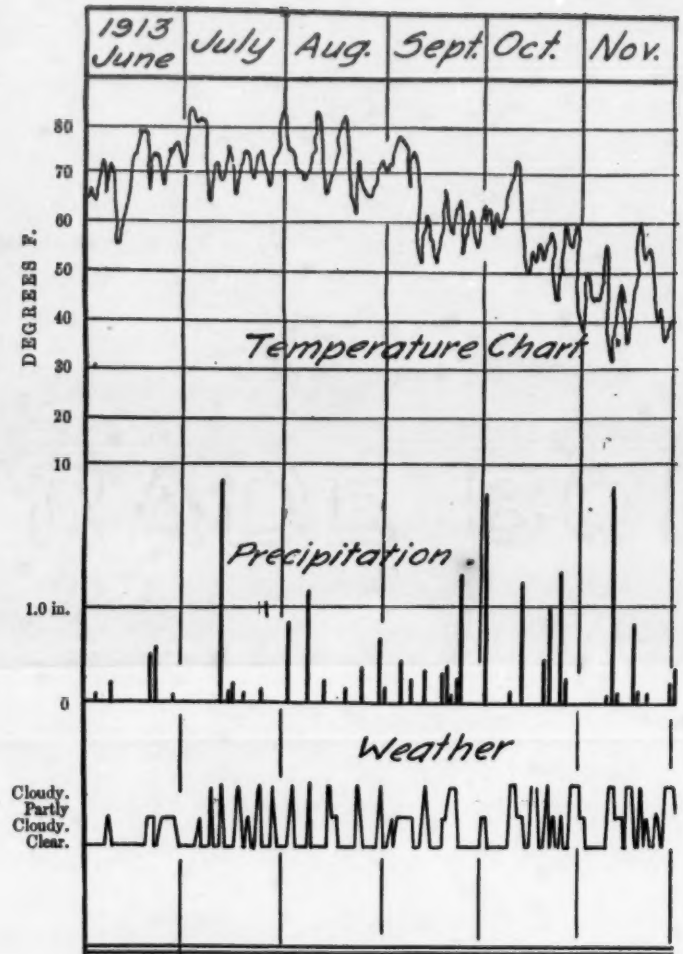
Slab z1.
Slab Length, 30 ft.
Measured Length, 20.2 ft.

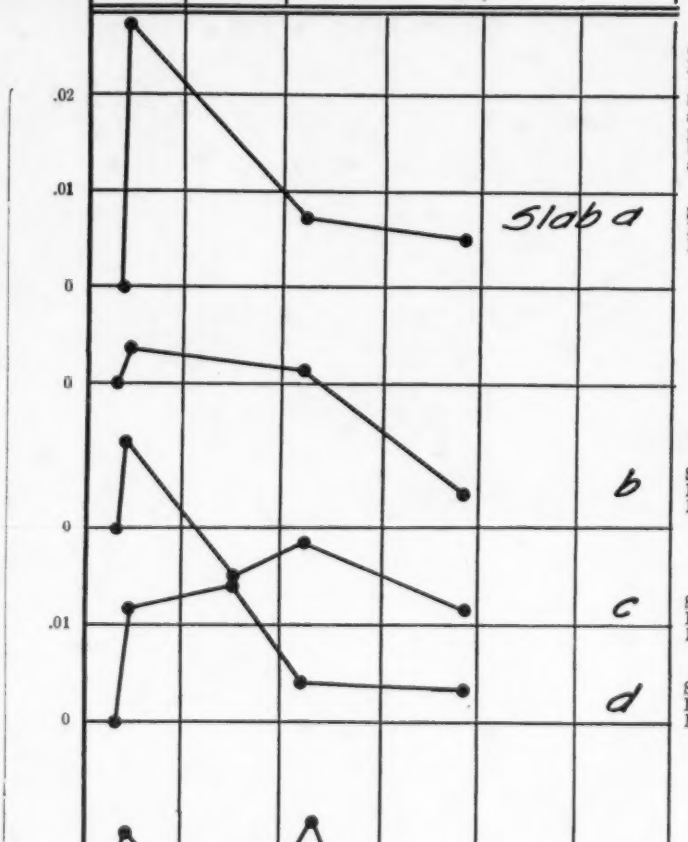
Slab z2.
Slab Length, 30 ft.
Measured Length, 19.7 ft.

Slab z3.
Slab Length, 30 ft.
Measured Length, 16.4 ft.

RESULTS OF MEASUREMENTS OF LINEAR CHANGES IN CONCRETE SLABS IN A CONCRETE ROAD ON MORRIS TURNPIKE, NEAR NEW VILLAGE, N. J.
OBSERVATIONS COVER 1 YEAR FROM OCTOBER, 1912.
RESULTS OF INVESTIGATIONS BY BUREAU OF STANDARDS.
FIGURE 2.

PLATE II.
PROCEEDINGS AMERICAN CONCRETE INSTITUTE.
VOL. X.
WIG AND GEVERT
ON
THE CONTRACTION AND EXPANSION
OF
CONCRETE ROADS.





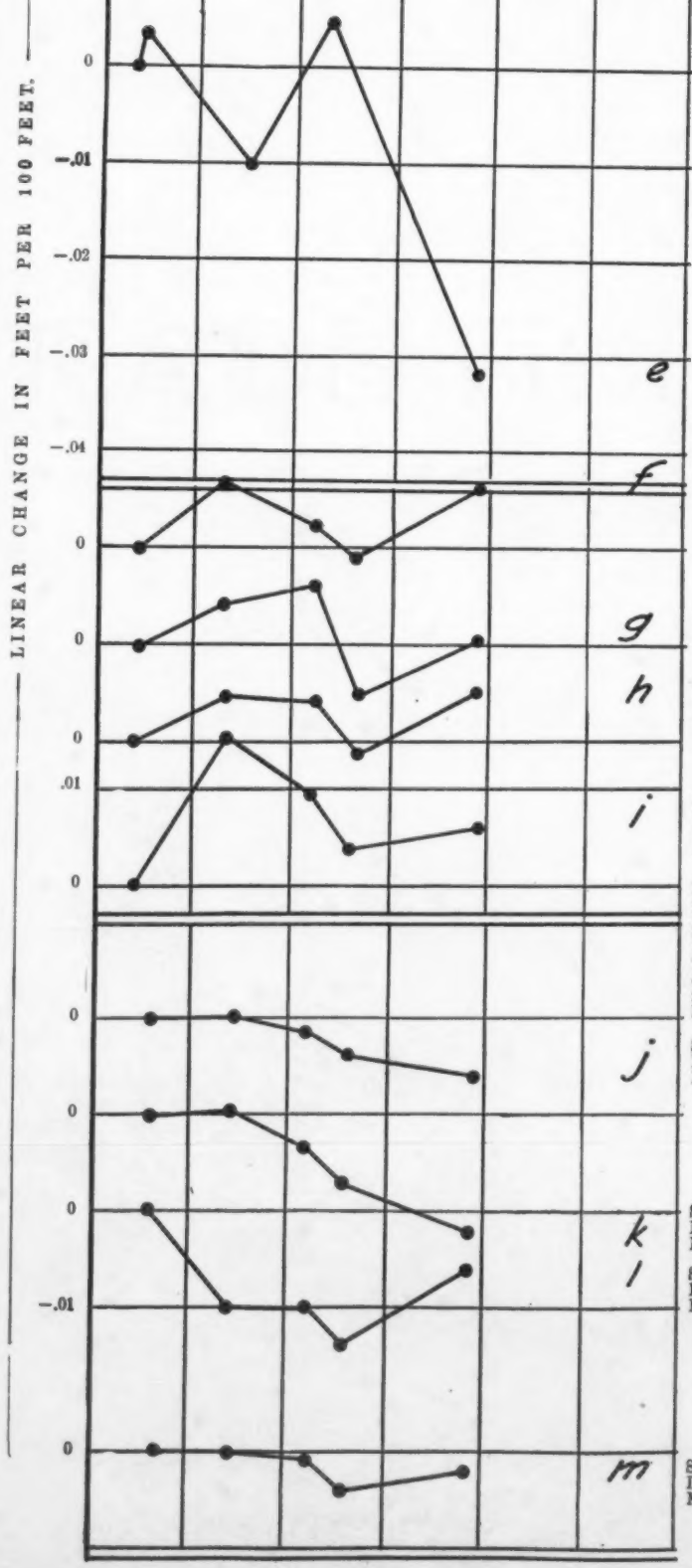
Course B. Easton Road, Nazareth, Pa.
Brand of cement, D; Kind of aggregate, limestone; Mixture, 1 : 2 : 3; Width, 16 ft.; Thickness, 7½ in. at center, 5 in. at sides. Sub-base, 8 in. Telford, taken up and replaced and rolled, and top sealed with loam. French drain on south side of road. Concrete placed June 5, 6, 7, 1913. Surface finished with wooden float and broomed crosswise. Concrete surface sprinkled after hardening and covered with earth and kept wet for seven days.

Slab a.
Length, 22.7 ft.
Measured Length, 18.7 ft.

Slab b.
Length, 26.2 ft.
Measured Length, 19.7 ft.

Slab c.
Length, 26.2 ft.
Measured Length, 13.1 ft.

Slab d.
Length, 22.6 ft.
Measured Length, 19.7 ft.



Slab e.
Length, 19.7 ft.
Measured Length, 16.4 ft.

Course C. Easton Road, Nazareth, Pa.
Brand of cement, E; Kind of aggregate, limestone; Mixture, 1 : 2 : 3; Width, 16 ft.; Thickness, 7½ in. at center, 5 in. at sides; Sub-base, 8 in. Telford, brought to grade of sub-base and sealed with loam, except Diagram i. Tile drain on north side, French drain on south side. Concrete placed June 9, 10, 11, 12, 1913. Surface finished with wooden float and broomed crosswise. Concrete surface sprinkled after hardening and covered with earth and kept wet for seven days.

Slab f.
Length, 31.2 ft.
Measured Length, 26.2 ft.

Slab g.
Length, 32.8 ft.
Measured Length, 26.2 ft.

Slab h.
Length, 32.8 ft.
Measured Length, 19.7 ft.

Slab i.
Length, 23.5 ft.
Measured Length, 23.0 ft.
Placed on old concrete base.

Course D. Easton Road, Nazareth, Pa.
Brand of cement, E; Kind of aggregate, limestone; Mixture, 1 : 2 : 3; Width, 16 ft.; Thickness, 7½ in. at center, 5 in. at sides; Sub-base, diagrams k, l, m, over old concrete base covered with loam; Diagram j-8 in. Telford brought to grade and sealed with loam. Tile drain on north side, French drain on south side of road. Concrete placed June 9, 10, 11, 12, 1913. Surface finished with wooden float and broomed crosswise. Concrete surface sprinkled after hardening and covered with earth and kept wet for seven days.

Slab j.
Length, 27.9 ft.
Measured Length, 26.2 ft.

Slab k.
Length, 32.8 ft.
Measured Length, 19.7 ft.

Slab l.
Length, 30.5 ft.
Measured Length, 26.2 ft.

Slab m.
Length, 28.0 ft.
Measured Length.

RESULTS OF MEASUREMENTS OF LINEAR CHANGES IN CONCRETE SLABS IN A CONCRETE ROAD ON EASTON ROAD NEAR NAZARETH, PA. OBSERVATIONS COVER 5 MONTHS FROM JUNE, 1913.
RESULTS OF INVESTIGATIONS BY BUREAU OF STANDARDS.
FIGURE 3.

PLATE III.
PROCEEDINGS AMERICAN CONCRETE INSTITUTE.
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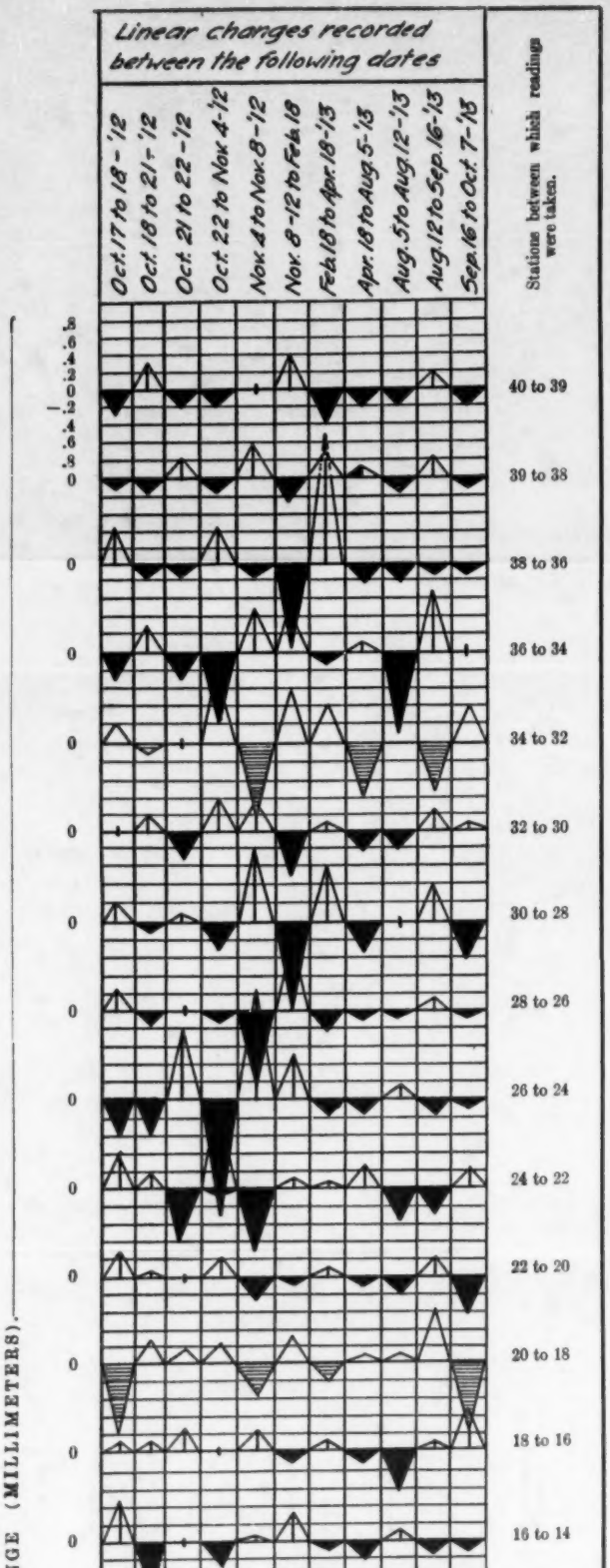
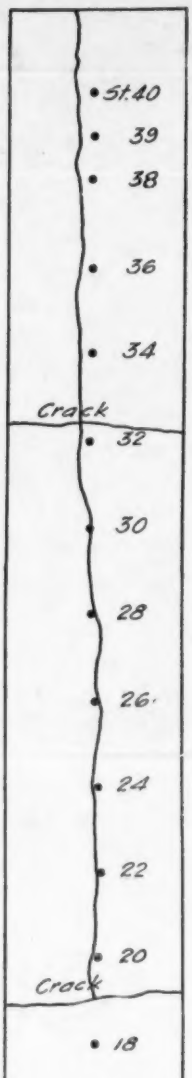
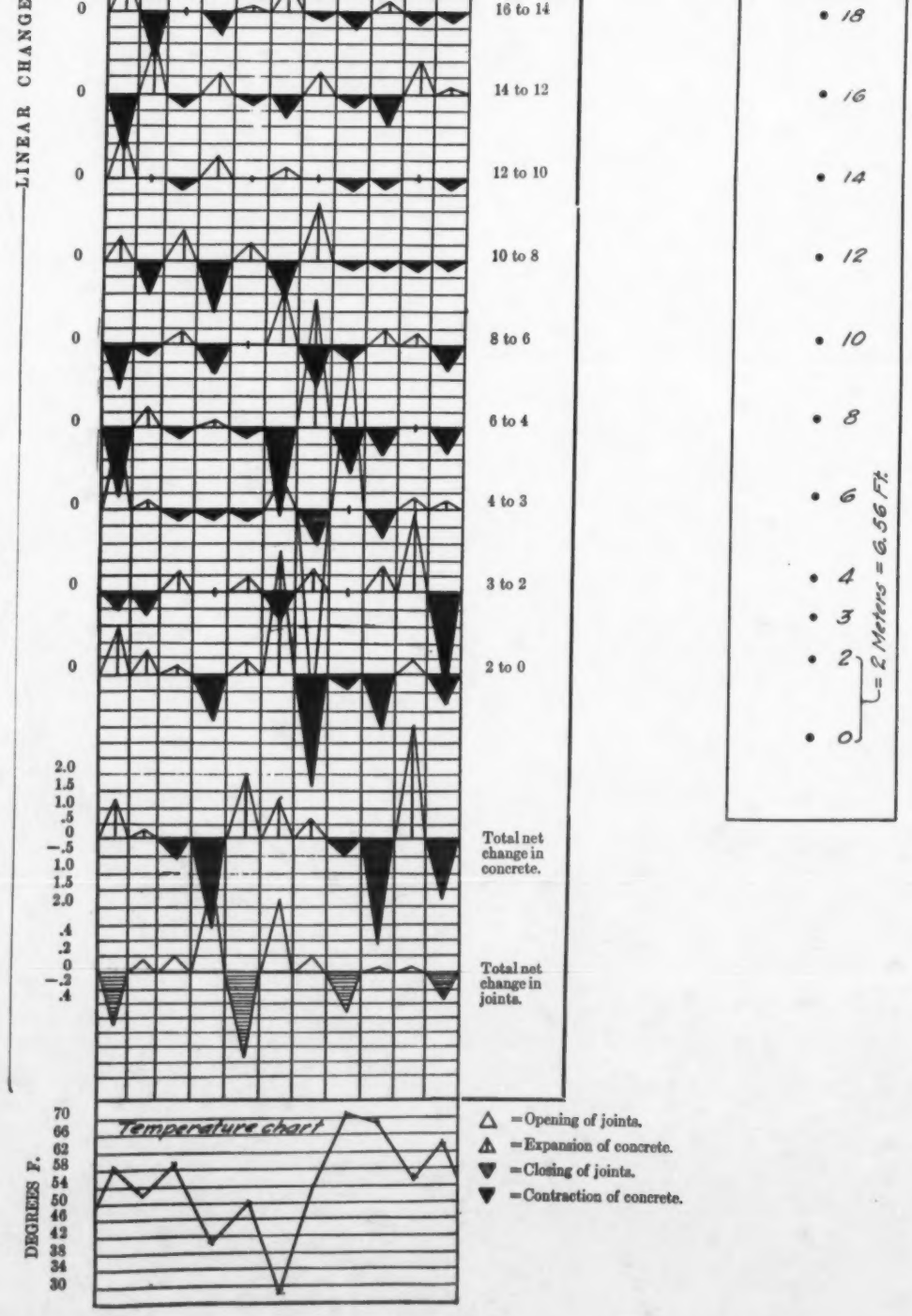


Concrete placed Oct. 16, 1912. Dolorway covering placed Nov. 12, 1912. Reference plugs placed Oct. 17, 1912. Construction of road: Mixture concrete 1 : 1½ : 3. Cement Sta. 0 to 7.7, Brand Ve. Sta 7.7 to 40, Brand Aa. Width 14 ft. Thickness 6 in. Not covered but sprinkled daily for 7 days. Grade, Sta. 0 to 14, 3.55% slope, Sta. 14 to 40, 2.9% Slope. Surface of concrete finished with template wooden float and broomed. Tile drain on north side of road. The stations plotted on the diagrams are numbered in accordance with the distance in meters from "0."

DIAGRAM OF ROADWAY SHOWING CRACKS AND LOCATION OF REFERENCE PLUGS.





LINEAR CHANGES OBSERVED OVER A PERIOD OF 14 MONTHS ON COURSE "C." MORRIS TURNPIKE NEAR NEW VILLAGE, N. J.
RESULTS OF INVESTIGATIONS OF THE BUREAU OF STANDARDS.
FIGURE 4.

PLATE IV.
PROCEEDINGS AMERICAN CONCRETE INSTITUTE.
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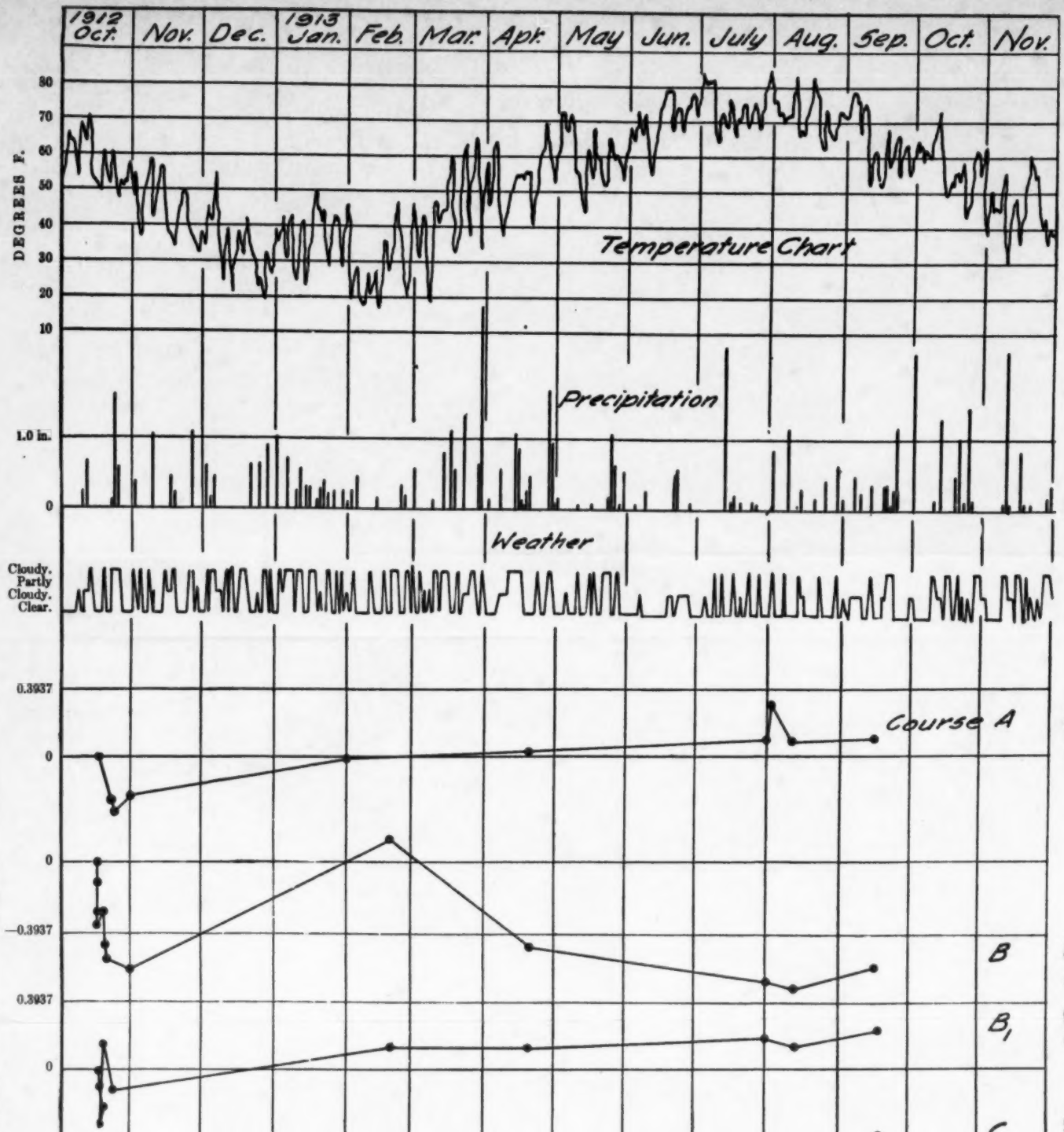
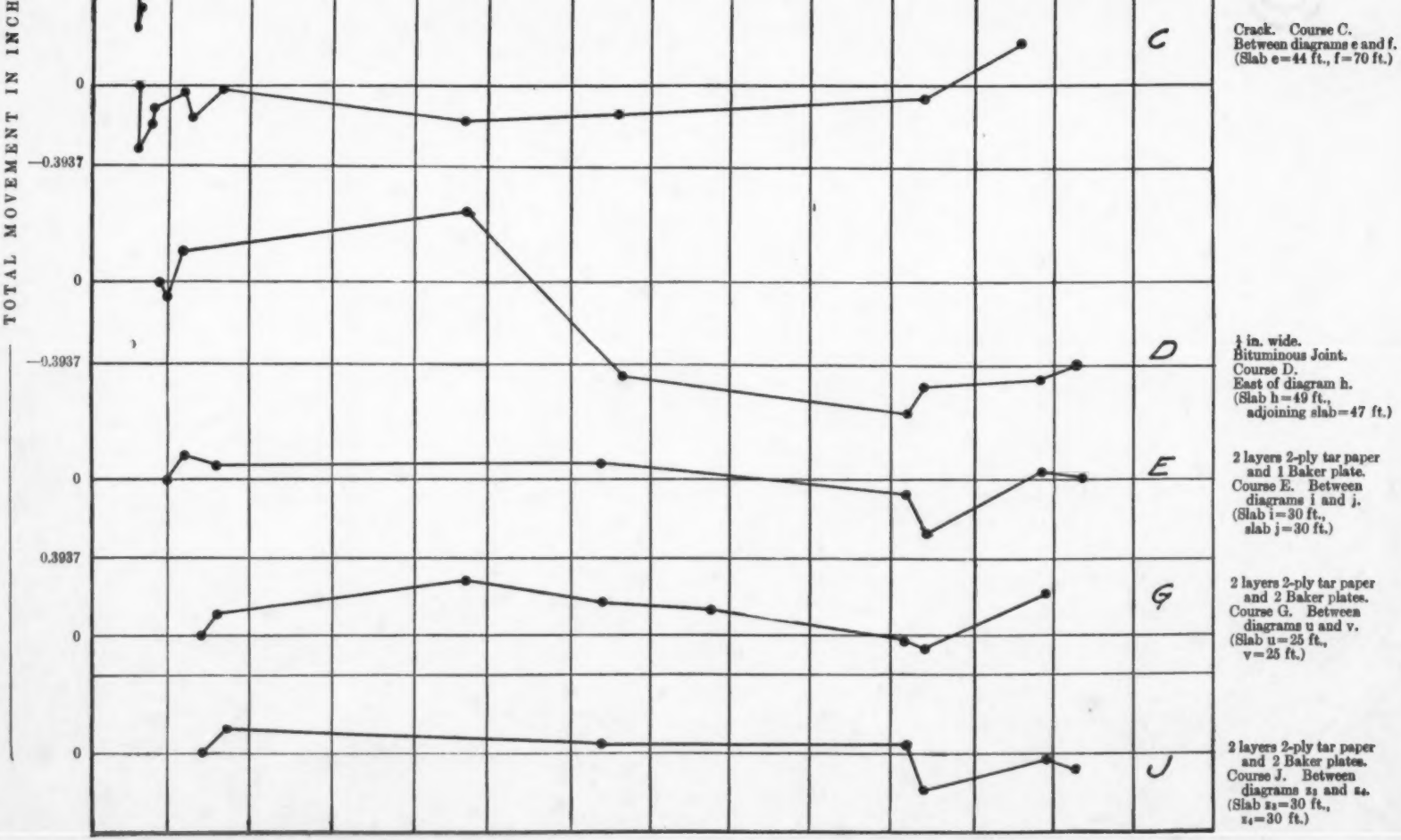


1 layer 2-ply tar paper. Course A. Between diagrams a and b. (Slab a=78 ft., b=52 ft.)

1 layer 2-ply tar paper. Course B. Between diagrams c and d. (Slab c=50 ft., d=57 ft.)

Crack. Course B. West of diagram c. (Slab c=50 ft., adjoining slab=42 ft.)

Crack. Course C.



RESULTS OF MEASUREMENTS ACROSS VARIOUS TYPES OF JOINTS IN CONCRETE ROAD ON MORRIS TURNPIKE NEAR NEW VILLAGE, N. J.
RESULTS OF INVESTIGATIONS BY BUREAU OF STANDARDS.
FIGURE 8

PLATE VIII.
PROCEEDINGS AMERICAN CONCRETE INSTITUTE.
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In Fig. 6 and 7 are shown some diagrams illustrating the possible effect of friction on the sub-base on the linear contraction, and the effect of temperature change in slabs with assumed fixed ends made up of sections having unequal moduli of elasticity, as an explanation of the variation in observations made on the foregoing roads. Thus if the conditions illustrated in these diagrams maintain even in part in the road slabs and such must be the case as a truly uniform friction on the sub-base and uniform quality of concrete is not now attained the observed movement can not be uniform throughout the slab.

In Fig. 8 is shown the observed movements of various types of joints in the concrete road on Morris Turnpike, near New Village, N. J. It will be observed from this diagram that the greatest movement occurred with the $\frac{1}{4}$-in. wide bituminous joint. The least movement occurred with the Baker plates with tar paper between. Since the concrete appears to be capable of withstanding all compressive stresses which may be caused by temperature or moisture variation, it would seem that a tight contraction joint would be satisfactory.

It should not be considered that lack of uniformity in the movements of the various concrete slabs indicates a lack of concordance of observations, because in many cases these differences can be explained by local conditions, such as change in character of sub-base, change of grade, difference in drainage, capillarity of sub-soil, etc.

This paper is not intended as a complete digest of the observations made upon these concrete roads, but it presents a summary of data obtained with some general discussion which appears to indicate, first, that the magnitude of the expansion and contraction caused by a change in moisture content of the concrete is far greater than that caused by temperature variation, and second, that the friction on the sub-base probably has considerable effect upon the movement of the concrete slab.

It is proposed to place during 1914 some concrete slabs on the grounds of the Bureau of Standards where conditions can be better controlled and careful observations can be made at more frequent intervals.

DISCUSSION.

Mr. Wilson. MR. PERCY H. WILSON.—Did I understand Mr. Wig to say that he had noticed in concrete roads which had cracked transversely, that one slab had raised above the other at these cracks?

Mr. Wig. MR. RUDOLPH J. WIG.—No, I was referring to the transverse joint and recommended that roads be built not as a continuous concrete slab and permitted to crack transversely where it will, as the transverse crack may not be perpendicular to the surface of the road and there may be a tendency for one slab to crawl above the other as in the case of one joint observed on the Morris Turnpike; also of course there must be a weakening of the concrete for a section each side of the crack which was stressed beyond the elastic limit.

Mr. Wilson. MR. WILSON.—Was the slab that raised above the other at a transverse crack?

Mr. Wig. MR. WIG.—Yes, in the case where one slab raised above the other it was where the joint was not placed perpendicular to the face, but the joint was at an angle, and one slab raised up above the other when expansion occurred.

The President. PRESIDENT HUMPHREY.—While the data which Mr. Wig has presented seems to indicate that the movement of the pavement is due to moisture, it is probable that later investigations will show that the real cause of contraction and expansion is temperature. In the case of the laboratory tests of Professor White, made on very small test pieces, about one-half inch square in section, the penetration of moisture, in such a small mass, has some effect; but on the other hand, as the concrete increases in thickness this effect will materially decrease, and it will decrease also with the density. It certainly is a fact that the movement in large slabs results from changes in temperature and not from changes in the moisture content; the penetration of moisture, even under prolonged periods of humidity, would not be very extensive as regards the mass, would not penetrate very far from the surface, and could not therefore affect a large mass. While

it would seem apparent from the data that have been submitted that the movement of these pavements was due to variations in the moisture content and not to changes in temperature, it is probable that continued experiments under these same conditions will show that temperature and not moisture content is the principal cause. Measurements of movements in structures correspond to about what would be expected from the expansion and contraction due to temperature changes. The President.

MR. WIG.—I would like to say that when we started this work we knew little concerning the movements which might be expected, although we did expect, as Mr. Humphrey states, that the maximum expansion would be obtained during the summer months. We not only obtained the maximum contraction during the summer months, but the observations show that this contraction, due to loss of moisture, is sufficient not only to entirely overcome the expansion due to rise in temperature, but enough greater to cause very appreciable contraction. Also during the winter months we obtained an expansion very much greater than during the summer months in many cases. These statements are not based upon observations made on laboratory specimens, but rather upon observations made upon actual road slabs in natural position. Mr. Wig.

PRESIDENT HUMPHREY.—I understand that perfectly. I referred to the laboratory test piece, because it was evident that with a relatively small mass and a large surface area, the relatively large penetration of moisture would affect the mass; whereas in the pavement seven inches thick the relative effect of moisture on that larger mass must be materially less and would decrease as the mass increases; it is hard to believe that the porosity of the slab, if laid under proper conditions, would be so great that the moisture from atmospheric conditions would so penetrate that mass as to produce expansion and contraction that would exceed that due to changes in temperature. I do not wish to be understood as saying that it is not so, as it may be that later investigations will confirm these tests. The President

We appreciate the work that is being done by the Bureau of Standards in this connection, but it would be wise to suspend judgment on the results until the evidence is more conclusive than I think it is at present.

Mr. Larned. MR. E. S. LARNED.—I would like to suggest the advisability, when making experiments of this sort, of determining the movement in concrete, that the comparisons be drawn from observations on one given pavement and not compared with observations taken on a variety of different pavements in different localities and pavements of different widths. There are so many factors entering into this problem, and of which we may know very little, that we are apt to be led to erroneous conclusions if we do not limit our comparisons to results taken on a given pavement. And of course it would be desirable to select a pavement for this observation that would afford a variety in soil conditions, a variety in moisture conditions, a variety in traffic conditions, and I think with a little care that could be found.

I would like to ask Mr. Wig if he has ever considered the reason for a greater contraction in August than in the winter months as perhaps resulting in the capacity of the concrete to absorb water quicker in August than in the winter. The concrete is probably at a higher sustained temperature all during the summer months than in the winter months; and it has been my observation that any crystalline substance will absorb water more readily when warm than cold; and I believe that it is the ground water rather than surface that is affecting the expansion of concrete. It is seldom that we have a prolonged shower, it is seldom that the pavement is actually under water. We use our pavement on ground that drains itself readily, and the water has very little chance for penetration. But it is never free of that influence if the water is in the foundation itself. I presume Mr. Wig has considered that, but I would like to know what he thinks of the suggestion.

Mr. Wig. MR. WIG.—Mr. Larned's statement is slightly in error. If the concrete absorbed moisture in the summer it would tend to cause expansion and not contraction, as he indicates; therefore, if the concrete is saturated with water and exposed to the highest temperature, it should show maximum expansion.

The effect of humidity on the expansion of concretes, cements and mortars is so great that one can practically predict a change in humidity in the atmosphere by careful observations upon such specimens. It is probable that very little water penetrates a concrete road slab from the top surface during an ordinary rain

storm, especially during the summer months, but the location of the ground water and the state of saturation of the subsoil should determine the moisture content of the concrete. Mr. Wig.

Where the ground water is very near the surface, the movement of the slab ought to conform more nearly to the temperature change, but where the ground water is excluded, a maximum contraction should obtain as shown for some of the slabs of the Nazareth Road.

PRESIDENT HUMPHREY.—There are two other points in connection with moisture in concrete which should be borne in mind. One is that when the pavement is first laid, there is present an excess of the water used in mixing, and as the concrete ages, the amount of absorption of moisture decreases. The President.

MR. P. H. BATES.—Mr. Wig's statements in regard to the effect of humidity in the atmosphere on concrete, have been confirmed by us at the Bureau of Standards' Laboratory at Pittsburgh on laboratory specimens of concrete. These specimens are about 42 in. long and 4 in. in cross section, made of $1:1\frac{1}{2}:4\frac{1}{2}$ concrete, using in every case the same aggregates but the various cements which have been burned at the experimental cement plant in Pittsburgh. These cements represent a great variety in composition, from very low silica to very high silica, from very low alumina to high alumina, and from low lime to high lime. The concrete was aged both in water and in air, in the latter case being subjected to all changes which may take place in humidity but not being subjected to any precipitation of either rain or snow. We have found in every case, excepting where unsound cements were used, that after a period of approximately six months, depending upon the nature of the cement used, all specimens kept in the air are affected much more by humidity changes than by temperature changes. Thus, if a specimen is measured a day or two after a heavy rain, it will be found that the specimen has increased in length over what it had been before the rain. If, after the rain, the humidity decreases considerably, the specimen will slowly decrease in length. All specimens kept in water, however, have shown so far a uniform gain in length. In case the cement has been unsound, we find that after about the same period as above mentioned, the concrete begins to expand and does so regardless of the humidity conditions and shows disintegration much sooner Mr. Bates.

Mr. Bates. than the specimens stored continuously in water. We consequently agree with Mr. Wig's statement that the moisture in the atmosphere has a marked influence, in fact a greater influence than the change in temperature, at least when the specimen is of the dimensions given above.

REPORT OF COMMITTEE ON CONCRETE ROADS AND STREET PAVEMENTS.

Your Committee presents the following for adoption:

Proposed standard specifications for one course concrete highway.

Proposed standard specifications for one course concrete street pavement.

Proposed standard specifications for two course concrete street pavement.

Respectfully submitted,

C. W. BOYNTON,
Chairman.
EDWARD N. HINES,
A. R. HIRST,
JOHN B. HITTELL,
FRED. CHARLES,
A. N. JOHNSON,
THOMAS H. MACDONALD,
JAMES R. MARKER,
H. G. SHIRLEY,
FRED. C. SMITH,
PERCY H. WILSON.

STANDARD SPECIFICATIONS FOR ONE COURSE CONCRETE HIGHWAY.

I. Materials.

Cement. 1. The *cement* shall meet the requirements of the Standard Specifications for Portland Cement, adopted by the American Society for Testing Materials, August 16, 1909, with all subsequent amendments and additions thereto adopted by said society and adopted by this Institute (Standard No. 1).

When the cement is not inspected at the place of manufacture it shall be stored a sufficient length of time to permit of inspecting and testing. The engineer shall be notified of the receipt of each shipment of cement.

Aggregate. 2. *Fine aggregate* shall consist of sand or screenings from clean, hard, durable, crushed rock or gravel consisting of quartzite grains or other equally hard material graded from fine to coarse, with the coarse particles predominating and passing, when dry, a screen, having $\frac{1}{4}$-inch openings. It shall be clean, hard, free from dust, loam, vegetable, or other deleterious matter. Not more than twenty (20) per cent shall pass a sieve having fifty (50) meshes per linear inch, and not more than five (5) per cent shall pass a sieve having one hundred (100) meshes per linear inch.

Fine aggregate containing more than three (3) per cent of clay or loam shall be washed before using.

Fine aggregate shall be of such quality that the mortar composed of one (1) part Portland cement and three (3) parts fine aggregate by weight, when made into briquettes, shall show a tensile strength at least equal to the strength of 1 to 3 mortar of the same consistency made with the same cement and Standard Ottawa sand.

In no case shall fine aggregate containing frost or lumps of frozen material be used.

3. *Coarse aggregate* shall consist of clean, hard, durable, crushed rock or gravel, graded in size, free from dust, loam, vegetable or other deleterious matter and shall contain no soft, flat or elongated particles. The size of the coarse aggregate shall be such as to pass a one and one-half ($1\frac{1}{2}$) inch round opening and be retained on a screen having one-quarter ($\frac{1}{4}$) inch openings. In no case shall coarse aggregate containing frost or lumps of frozen material be used.

4. *Natural mixed aggregate* shall not be used as it comes from deposits, but shall be screened and used as specified.

5. *Water* shall be clean, free from oil, acid, alkali or vegetable matter. **Water.**

6. *Reinforcement.*—Concrete pavements twenty (20) feet or more in width shall be reinforced with metal fabric. All reinforcement shall be free from excessive rust, scale, paint or coatings of any character which will tend to destroy the bond. All reinforcement shall develop an ultimate tensile strength of not less than 70,000 pounds per square inch and bend 180 deg. around one diameter and straighten without fracture. **Reinforcement.**

7. *Joint Filler* shall consist of prepared felt or similar material of approved quality having a thickness of not less than $\frac{1}{8}$ nor more than $\frac{1}{4}$ in. **Joint Filler.**

8. *Joint Protection Plates.*—Soft steel plates for the protection of the edges of the concrete at transverse joints shall be not less than $2\frac{1}{2}$ in. in depth and not less than $\frac{1}{8}$ in. at any point nor more than $\frac{1}{4}$ in. in average thickness. The plates shall be of such form as to provide for rigid anchorage to the concrete. The type and method of installation of joint protection plates shall be approved by the engineer. **Joint Protection Plates.**

9. *Shoulders.*—Materials for the construction of shoulders shall be approved by the engineer. **Shoulders.**

II. GRADING.

10. *Defined.*—The term "grading" shall include all cuts, fills, ditches, borrow pits, approaches and all earth moving for whatever purpose, where such work is an essential part of or necessary to the prosecution of the contract. When to bring the

surface to grade, a fill of one (1) foot or less is required, the area shall be thoroughly grubbed. All soft, spongy or yielding spots and all vegetable or other objectionable matter shall be removed and the space refilled with suitable material.

Engineer's Stakes

11. *Stakes* will be set by the engineer for the center line, side of slopes, finished grade and other necessary points properly marked for the cut or fill.

Excess Material.

12. *Excess material* shall be disposed of as directed by the engineer, the free haul not to exceed ..... feet.

13. *Over-haul.*—Materials hauled a greater distance than the free haul from the place of excavation shall be paid for at the rate of ..... cents per cubic yard for each additional ..... feet.

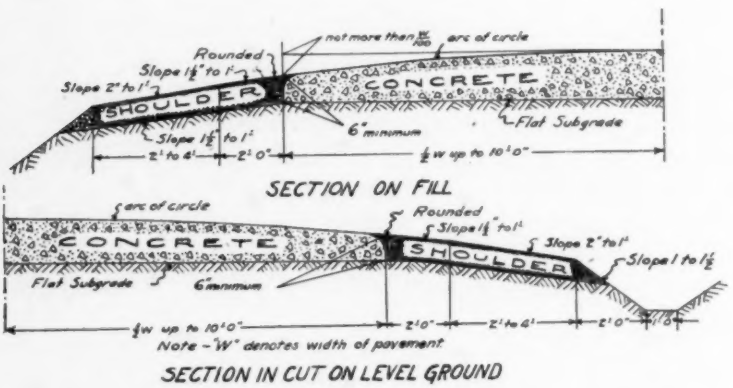

FIG. 1.—ONE COURSE CONCRETE HIGHWAY. SECTIONS ON FILL AND CUT.

Fills.

14. *Fills.*—Embankments shall be formed of earth or other approved materials and shall be constructed in successive layers, the first of which shall extend entirely across from the toe of the slope on one side to the toe of the slope on the other side, and successive layers shall extend entirely across the embankments from slope to slope. Each layer, which shall not exceed one (1) foot in depth, shall be thoroughly rolled with a roller weighing not less than five (5) tons nor more than ten (10) tons before the succeeding layer is placed. The roller shall pass over the entire area of the fill at least twice.

The sides of the embankment shall be kept lower than the

center during all stages of the work, and the surface maintained in condition for adequate drainage. The use of muck, quicksand, soft clay or spongy material which will not consolidate under the roller is prohibited.

When the material excavated from the cuts is not sufficient to make the fills shown on the plans, the contractor shall furnish the necessary extra material to bring the fills to the proper width and grade. When the earth work is completed, the cross-section of the road shall conform to the cross-sectional drawings and profile shown in Fig. 1.

15. All *slopes* shall be properly dressed to lines given by the engineer. **Slopes.**

16. *Finished Grade.*—When the grade line is approached, the final grade stakes will be set, for which sufficient notice must be given to the engineer. **Finished Grade.**

NOTE.—In excavating cuts, it is considered advisable, when the line of the sub-grade is approached, to compact the remaining material by rolling. The depth of material left in the cut to be compressed to the finished grade by rolling will depend upon the character of the material.

III. DRAINAGE.

17. *Drainage.*—The contractor shall construct such drainage ditches as will insure perfect sub- and surface-drainage during construction and such work shall be completed to the satisfaction of the engineer, prior to the preparation of the roadbed, as herein specified. **Drainage.**

Tile drains shall be placed as shown in the drawings attached hereto. Tile to be laid in the trench at least ..... (.....) inches wide and ..... (.....) feet deep below the established grade of the finished pavement. Such trench shall be back filled with crushed stone or pit run gravel, with sand removed, which after light tamping shall be ..... (.....) inches in depth.

Open ditches must be constructed along the concrete road as shown in Fig. 1, the dimensions, side slopes and grade of said ditches being as shown on the cross-section and profile.

At the time of the acceptance of the road, the ditches must be in perfect condition, with clean slopes and bottom, containing no obstructions to the flow of water.

IV. SUB-GRADE.

Sub-Grade.

18. *Construction.*—The bottom of the excavation or top of the fill, when completed, shall be known as the sub-grade, and shall be at all places true to the elevation as shown on the plans attached hereto.

The roadway shall be graded to the proper sub-grade to permit of the specified thickness of paving materials being laid to bring the finished surface of the pavement to the lines and grades as shown on the plans.

The sub-grade shall be brought to a firm, unyielding surface by rolling the entire area with a self-propelled roller weighing not less than ten (10) tons, and all portions of the surface of the sub-grade which are inaccessible to the roller shall be thoroughly tamped with a hand tamp weighing not less than fifty (50) pounds, the face of which shall not exceed 100 square inches in area. All soft, spongy or yielding spots and all vegetable or other objectionable matter shall be entirely removed and the space refilled with suitable material.

Where considered necessary or of assistance in producing a compact solid surface, the sub-grade before being rolled shall be well sprinkled with water.

When the concrete pavement is to be constructed over an old roadbed composed of gravel or macadam, and the concrete is to be wider than the old gravel or macadam road, the latter shall be entirely loosened and the material spread for the full width of the roadbed and rolled. All interstices shall be filled with fine material, and rolled to make a dense, tight surface of the roadbed.

19. *Acceptance.*—No concrete shall be deposited upon the sub-grade until it is checked and accepted by the engineer.

20. *Completion.*—Upon the sub-grade thus formed shall be laid the concrete pavement as shown in Fig. 1.

V. FORMS.

Forms.

21. *Materials.*—The forms shall be free from warp, of sufficient strength to resist springing out of shape, and shall be equal in width to the thickness of the pavement at the edges. Wooden forms shall be of not less than two (2) inch stock and shall be capped with two (2) inch angle iron.

22. *Setting.*—The forms shall be well staked or otherwise held to the established line and grades, and the upper edges shall conform to the established grade of the road.

23. *Treatment.*—All mortar and dirt shall be removed from the forms that have previously been used.

VI. PAVEMENT SECTION.

Pavement Section.

24. *Width, Thickness of Concrete and Crown.*—The concrete pavement shall be ..... (.....) feet wide, ... (.....) inches in depth at center and ..... (.....) inches in depth at the sides. The finished surface shall conform to the arc of a circle, as shown on Fig. 1.

NOTE.—Crown shall be not more than one-one-hundredth (1/100) of the width. The thickness of the concrete at the edges shall not be less than six (6) inches.

VII. JOINTS.

Joints.

25. *Width and Location.*—Transverse joints shall be not less than one-quarter ($\frac{1}{4}$) inch nor more than three-eighths ($\frac{3}{8}$) inch in width, and shall be placed across the pavement perpendicular to the center line, not more than thirty-five (35) feet apart. When a curb is specified or where pavement abuts a building, a joint not less than one-quarter ($\frac{1}{4}$) inch wide shall be placed between it and the pavement. All joints shall extend through the entire thickness of the pavement and shall be perpendicular to its surface.

26. *Protection of Joints.*—The concrete at transverse joints shall be protected with soft steel joint protection plates which shall be rigidly anchored to the concrete. The installation of the metal protection plates shall meet with the approval of the engineer. The surface edges of the metal plates shall conform to the finished surface of the concrete, as shown in Fig. 1.

All joints over one-quarter ($\frac{1}{4}$) inch high or one-half ($\frac{1}{2}$) inch low shall be removed.

28. *Joint Filler.*—All joints shall be formed by inserting during construction and leaving in place the required thickness of joint filler which shall extend through the entire thickness of the pavement.

VIII. MEASURING MATERIALS AND MIXING CONCRETE.

Measuring Materials.

28. *Measuring.*—The method of measuring the materials for the concrete, including water, shall be one which will insure separate and uniform proportions of each of the materials at all times. A bag of Portland cement (94 lbs. net) shall be considered one (1) cubic foot.

Mixing.

29. *Mixing.*—The materials shall be mixed to the desired consistency in a batch mixer of approved type, and mixing shall continue for at least forty-five (45) seconds after all materials are in the drum. The drum shall be completely emptied before mixing successive batches. The drum of the mixer used shall revolve at a speed not less than the minimum nor more than the maximum number of revolutions shown in the following table:

Rated Capacity, cu. ft. Unmixed Material.	Capacity, Bags of Cement in 1:2½:3 mix.	Revolutions per Minute of Drum.	
		Min.	Max.
7 to 11	1	15	21
12 to 17	2	12	20
18 to 23	3	12	20
24 to 29	4	11	17
30 to 33	5	10	15

Retempering.

30. *Retempering* of mortar or concrete which has partially hardened, that is, mixing with additional materials or water, shall not be permitted.

Proportions.

31. *Proportions.*—The concrete shall be mixed in the proportions of one (1) bag of Portland cement to not more than two (2) cubic feet of fine aggregate and not more than three (3) cubic feet of coarse aggregate, and in no case shall the volume of the fine aggregate be less than one-half ($\frac{1}{2}$) the volume of the coarse aggregate.

A cubic yard of concrete in place between neat lines shall contain not less than one and seven-tenths (1.7) barrels of cement.

The engineer shall compare the calculated amount of cement required according to these specifications and plans attached hereto with the amounts actually used in each section of concrete, between successive transverse joints, as determined by actual count of the number of bags of cement used in each section. If the amount of cement used in any three adjacent sections (between transverse joints) is less by two (2) per cent, or if the

amount of cement used in any one section is less by five (5) per cent, than the amount hereinbefore specified, the contractor agrees to remove all such sections and to rebuild the same according to these specifications at his expense.

32. *Consistency.*—The materials shall be mixed with sufficient water to produce a concrete which when deposited will settle to a flattened mass, but shall not be so wet as to cause a separation of the mortar from the coarse aggregate in handling. Consistency.

IX. REINFORCING.

33. *Reinforcing.*—Concrete pavements twenty (20) feet or more in width shall be reinforced. The cross-sectional area of the reinforcing metal running parallel to the center line of the pavement shall amount to at least 0.038 square inch per foot of pavement width and the cross-sectional area of reinforcing metal, which is perpendicular to the center line of the pavement, shall amount to at least 0.049 square inch per foot of pavement length. Reinforcing.

Reinforcing metal shall not be placed less than two (2) inches from the finished surface of the pavement and otherwise shall be placed as shown on the drawings. The reinforcing metal shall extend to within two (2) inches of all joints, but shall not cross them. Adjacent widths of fabric shall be lapped not less than four (4) inches.

X. PLACING CONCRETE.

34. *Placing.*—Immediately prior to placing the concrete, the sub-grade shall be brought to an even surface. The surface of the sub-grade shall be thoroughly wet when the concrete is placed. Placing Concrete

After mixing, the concrete shall be deposited rapidly in successive batches upon the sub-grade prepared as hereinbefore specified. The concrete shall be deposited to the required depth and for the entire width of the pavement, in a continuous operation, between transverse joints without the use of intermediate forms or bulkheads.

In case of a breakdown concrete shall be mixed by hand to complete the section or an intermediate transverse joint placed as hereinbefore specified at the point of stopping work. Any concrete in excess of that needed to complete a section at the stopping of work shall not be used in the work.

35. *Finishing.*—The surface of the concrete shall be struck off by means of a template or strike board which shall be moved with a combined longitudinal and cross-wise motion. When the strike board is within three (3) feet of a transverse joint it shall be lifted to the joint and the pavement struck by moving the strike board away from the joint; any excess concrete shall be removed. Concrete adjoining the metal protection plates at transverse joints shall be dense in character and any holes left by removing any device used in installing the metal protection plates shall be immediately filled with concrete.

After being brought to the established grade with the template or strike board, the concrete shall be finished from a suitable bridge, no part of which shall come in contact with the concrete. The concrete shall be finished with a wood float in a manner to thoroughly compact it and produce a surface free from depressions or inequalities of any kind. The finished surface of the pavement shall not vary more than one-quarter ($\frac{1}{4}$) inch from the true shape.

The edges of the pavement shall be rounded as shown in Fig. 1.

XI. PROTECTION.

Protection.

36. *Curing and Protection.*—Excepting as hereinafter specified, the surface of the pavement shall be sprayed with water as soon as the concrete is sufficiently hardened to prevent pitting, and shall be kept wet until an earth covering is placed. As soon as it can be done without damaging the concrete, the surface of the pavement shall be covered with not less than two (2) inches of earth or other material which will afford equally good protection, which cover shall be kept moist for at least ten (10) days. When deemed necessary or advisable by the engineer, freshly laid concrete shall be protected by a canvas covering until the earth covering can be placed.

If at the time the pavement is laid or during the period of curing the temperature during the daytime drops below 50 degrees Fahrenheit, sprinkling and covering of the pavement shall be omitted at the direction of the engineer.

Under the most favorable conditions for hardening, in hot weather, the pavement shall be closed to traffic for a least fourteen (14) days, and in cool weather for an additional time, to be determined by the engineer.

The contractor shall erect and maintain suitable barriers to protect the concrete from traffic and any part of the pavement damaged from traffic or other causes occurring prior to its official acceptance, shall be repaired or replaced by the contractor at his expense in a manner satisfactory to the engineer. Before the pavement is thrown open to traffic the covering shall be removed and disposed of as directed by the engineer.

37. *Temperature Below 35 Degrees Fahrenheit.*—Concrete shall not be mixed or deposited when the temperature is below freezing. **Freezing.**

If at any time during the progress of the work the temperature is, or in the opinion of the engineer will, within twenty-four (24) hours drop to 35 degrees Fahrenheit, the water and aggregates shall be heated and precautions taken to protect the work from freezing for at least ten (10) days. In no case shall concrete be deposited upon a frozen sub-grade.

XII. SHOULDERS.

38. *Construction.*—When shoulders are required they shall be built upon the properly prepared sub-grade, as shown on the cross-sectional drawing, Fig. 1. The work shall be done to the entire satisfaction of the engineer. **Shoulders.**

STANDARD SPECIFICATIONS FOR ONE COURSE CONCRETE STREET PAVEMENT.

I. Materials.

Cement.

1. The *cement* shall meet the requirements of the Standard Specifications for Portland Cement, adopted by the American Society for Testing Materials, August 16, 1909, with all subsequent amendments and additions thereto adopted by said Society and adopted by this Institute (Standard No. 1).

When the cement is not inspected at the place of manufacture it shall be stored a sufficient length of time to permit of inspecting and testing. The engineer shall be notified of the receipt of each shipment of cement.

Fine Aggregate.

2. *Fine aggregate* shall consist of sand or screenings from clean, hard, durable, crushed rock or gravel consisting of quartzite grains or other equally hard material graded from fine to coarse with the coarse particles predominating and passing, when dry, a screen having ¼-inch openings. It shall be clean, hard, free from dust, loam, vegetable, or other deleterious matter. Not more than twenty (20) per cent shall pass a sieve having fifty (50) meshes per linear inch, and not more than five (5) per cent shall pass a sieve having one hundred (100) meshes per linear inch.

Fine aggregate containing more than three (3) per cent of clay or loam shall be washed before using.

Fine aggregate shall be of such quality that the mortar composed of one (1) part Portland cement and three (3) parts fine aggregate by weight, when made into briquettes, shall show a tensile strength at least equal to the strength of 1 to 3 mortar of the same consistency made with the same cement and Standard Ottawa sand.

In no case shall fine aggregate containing frost or lumps of frozen material be used. **Coarse Aggregate.**

3. *Coarse aggregate* shall consist of clean, hard, durable, crushed rock or gravel, graded in size, free from dust, loam, vegetable or other deleterious matter and shall contain no soft, flat or elongated particles. The size of the coarse aggregate shall be such as to pass a one and one-half ($1\frac{1}{2}$) inch round opening and be retained on a screen having one-quarter ($\frac{1}{4}$) inch openings. In no case shall coarse aggregate containing frost or lumps of frozen material be used.

4. *Natural mixed aggregate* shall not be used as it comes from deposits, but shall be screened and used as specified. **Natural Mixed Aggregate.**

5. *Water* shall be clean, free from oil, acid, alkali or vegetable matter. **Water.**

6. *Reinforcement.*—Concrete pavements twenty (20) feet or more in width shall be reinforced with metal fabric. All reinforcement shall be free from excessive rust, scale, paint or coatings of any character which will tend to destroy the bond. All reinforcement shall develop an ultimate tensile strength of not less than 70,000 pounds per square inch and bend 180 deg. around one diameter and straighten without fracture. **Reinforcement.**

7. *Joint Filler* shall consist of prepared felt or similar material of approved quality having a thickness of not less than $\frac{1}{8}$ nor more than $\frac{1}{4}$ in. **Joint Filler.**

8. *Joint Protection Plates.*—Soft steel plates for the protection of the edges of the concrete at transverse joints shall be not less than $2\frac{1}{2}$ in. in depth and not less than $\frac{1}{8}$ in. at any point nor more than $\frac{1}{4}$ in. in average thickness. The plates shall be of such form as to provide for rigid anchorage to the concrete. The type and method of installation of joint protection plates shall be approved by the engineer. **Joint Protection Plates.**

9. *Shoulders.*—Materials for the construction of shoulders shall be approved by the engineer. **Shoulders.**

II. GRADING.

10. *Defined.*—The term "grading" shall include all cuts, fills, approaches and all earth moving for whatever purpose where such work is an essential part of or necessary to the prosecution

of the contract. When to bring the surface to grade, a fill of one (1) foot or less is required, the area shall be thoroughly grubbed. All soft, spongy or yielding spots and all vegetable or other objectionable matter shall be removed and the space refilled with suitable material.

Engineer's Stakes. 11. *Stakes* will be set by the engineer for the center line, side of slopes, finished grade and other necessary points properly marked for the cut or fill.

Excess Material. 12. *Excess Material* shall be disposed of as directed by the engineer, the free haul not to exceed .....feet.

13. *Over-haul.*—Materials hauled a greater distance than the free haul from the place of excavation shall be paid for at the

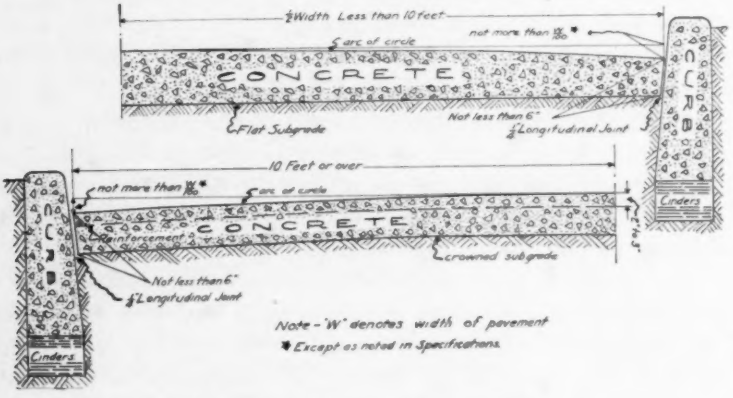

FIG. 1.—ONE COURSE CONCRETE PAVEMENT.

rate of ..... cents per cubic yard for each additional ..... feet.

Fills. 14. *Fills.*—Embankments shall be formed of earth or other approved materials and shall be constructed in successive layers, the first of which shall extend entirely across from the toe of the slope on one side to the toe of the slope on the other side, and successive layers shall extend entirely across the embankments from slope to slope. Each layer, which shall not exceed one (1) foot in depth, shall be thoroughly rolled with a roller weighing not less than five (5) tons nor more than ten (10) tons before the succeeding layer is placed. The roller shall pass over the entire area of the fill at least twice.

The sides of the embankment shall be kept lower than the center during all stages of the work and the surface maintained in condition for adequate drainage. The use of muck, quicksand, soft clay or spongy material which will not consolidate under the roller is prohibited.

When the material excavated from the cuts is not sufficient to make the fills shown on the plans, the contractor shall furnish the necessary extra material to bring the fills to the proper width and grade. When the earth work is completed, the cross-section of the road shall conform to the cross-sectional drawings and profile shown in Fig. 1.

15. All *slopes* must be properly dressed to a line given by the engineer. **Slopes.**

16. *Finished Grade.*—When the grade line is approached the final grade stakes will be set, for which sufficient notice must be given to the engineer. **Finished Grade.**

NOTE.—In excavating cuts, it is considered advisable, when the line of the sub-grade is approached, to compact the remaining material by rolling. The depth of material left in the cut to be compressed to the finished grade by rolling, will depend upon the character of the material.

III. DRAINAGE.

17. *Drainage.*—The contractor shall construct tile or other drains as shown in the drawings attached hereto. Tile to be laid in the trench at least ..... (.....) inches wide, and ..... (.....) feet deep below the top of the adjacent curb. Such trench shall be back filled with crushed stone or pit run gravel with sand removed, which after light tamping shall be ..... (.....) inches in depth. **Drainage.**

18. All *catch basin* and *manhole tops* and all covers of openings of any kind shall be readjusted to the grade by the contractor at his expense. **Catch Basins.**

IV. SUB-GRADE.

19. *Construction.*—The bottom of the excavation or the top of the fill when completed shall be known as the sub-grade and shall be at all places true to the elevation as shown on the plans attached hereto. **Sub-Grade.**

The street shall be graded from curb to curb to the proper sub-grade to permit of the specified thickness of paving materials being laid to bring the finished surface of the pavement to the lines and grades as shown on the plans.

The sub-grade shall be brought to a firm, unyielding surface by rolling the entire area with a self-propelled roller weighing not less than ten (10) tons, and all portions of the surface of the sub-grade which are inaccessible to the roller shall be thoroughly tamped with a hand tamp weighing not less than fifty (50) pounds, the face of which shall not exceed 100 square inches in area. All soft, spongy or yielding spots and all vegetable or other objectionable matter shall be entirely removed and the space refilled with suitable material.

Where considered necessary or of assistance in producing a compact solid surface the sub-grade, before being rolled, shall be well sprinkled with water.

When the concrete pavement is to be constructed over an old roadbed composed of gravel or macadam, and the concrete is to be wider than the old gravel or macadam road, the latter shall be entirely loosened and the material spread for the full width of the roadbed and rolled. All interstices shall be filled with fine material, and rolled to make a dense, tight surface of the roadbed.

20. *Acceptance.*—No concrete shall be deposited upon the sub-grade until it is checked and accepted by the engineer.

21. *Completion.*—Upon the sub-grade thus formed shall be laid the concrete pavement as shown in Fig. 1.

V. FORMS.

Forms.

22. *Materials.*—The forms shall be free from warp, of sufficient strength to resist springing out of shape, and shall be equal in width to the thickness of the pavement at the edges. Wooden forms shall be of not less than two (2) inch stock and shall be capped with two (2) inch angle iron.

23. *Setting.*—The forms when required shall be well staked or otherwise held to the established line and grades and the upper edges shall conform to the established grade of the street.

24. *Treatment.*—All mortar and dirt shall be removed from the forms that have been previously used.

VI. PAVEMENT SECTION.

Pavement Section.

25. *Width, Thickness of Concrete and Crown.*—The concrete pavement shall be ..... (.....) feet wide, ... (.....) inches in depth at center and ..... (.....) inches in depth at the sides. The finished surface shall conform to the arc of a circle, as shown on the plans attached hereto.

NOTE.—The thickness of the concrete at the edges shall not be less than six (6) inches. When pavements twenty (20) feet or less in width are to be built on approximately level ground and a flat sub-grade is to be used sufficient fall for drainage at the sides of the pavement along the curb shall be provided by giving the roadbed the same grade as that proposed for the gutter. The crown of all pavements shall not be more than one-one-hundredth (1/100) of the width, except when deemed advisable by the engineer—the crown of a pavement built on a crowned sub-grade may be increased to one-fiftieth (1/50) of the width to provide sufficient fall for drainage along the sides of the pavement at the curb.

VII. JOINTS.

Joints.

26. *Width and Location.*—Transverse joints shall be not less than one-quarter ($\frac{1}{4}$) inch nor more than three-eighths ($\frac{3}{8}$) inch in width, and shall be placed across the pavement perpendicular to the center line, not more than thirty-five (35) feet apart. A longitudinal joint, not less than one-quarter ($\frac{1}{4}$) inch wide shall be constructed between the curb and the pavement. All joints shall extend through the entire thickness of the pavement and shall be perpendicular to its surface.

27. *Protection of Joints.*—The concrete at transverse joints shall be protected with soft steel joint protection plates which shall be rigidly anchored to the concrete. The type and installation of the metal protection plates shall meet with the approval of the engineer. The surface edges of the metal plates shall conform to the finished surface of the concrete, as shown in Fig. 1.

All joints over one-quarter ($\frac{1}{4}$) inch high or one-half ($\frac{1}{2}$) inch low shall be removed.

28. *Joint Filler.*—All joints shall be formed by inserting during construction and leaving in place the required thickness of joint filler which shall extend through the entire thickness of the pavement.

VIII. MEASURING MATERIALS AND MIXING CONCRETE.

Measuring Materials.

29. *Measuring.*—The method of measuring the materials for the concrete, including water, shall be one which will insure separate and uniform proportions of each of the materials at all times. A bag of Portland cement (94 lbs. net) shall be considered one (1) cubic foot.

Mixing.

30. *Mixing.*—The materials shall be mixed to the desired consistency in a batch mixer of approved type, and mixing shall continue for at least forty-five (45) seconds after all materials are in the drum. The drum shall be completely emptied before mixing successive batches. The drum of the mixer used shall revolve at a speed not less than the minimum nor more than the maximum number of revolutions shown in the following table:

Rated Capacity, cu. ft. Unmixed Material.	Capacity, Bags of Cement in 1 : 2 : 3 mix.	Revolutions per Minute of Drum. Min.	Max.
7 to 11	1	15	21
12 to 17	2	12	20
18 to 23	3	12	20
24 to 29	4	11	17
30 to 33	5	10	15

Retempering.

31. *Retempering* of mortar or concrete which has partially hardened, that is, mixing with additional materials or water, shall not be permitted.

Proportions.

32. *Proportions.*—The concrete shall be mixed in the proportions of one (1) bag of Portland cement to not more than two (2) cubic feet of fine aggregate and not more than three (3) cubic feet of coarse aggregate, and in no case shall the volume of the fine aggregate be less than one-half ($\frac{1}{2}$) the volume of the coarse aggregate.

A cubic yard of concrete in place between neat lines shall contain not less than one and seven-tenths (1.7) barrels of cement.

The engineer shall compare the calculated amount of cement required according to these specifications and plans attached hereto with the amounts actually used in each section of concrete, between successive transverse joints, as determined by actual count of the number of bags of cement used in each section. If the amount of cement used in any three adjacent sections (between transverse joints) is less by two per cent, or if the

amount of cement used in any one section is less by five per cent than the amount hereinbefore specified, the contractor agrees to remove all such sections and to rebuild the same according to these specifications, at his expense.

33. *Consistency.*—The materials shall be mixed with sufficient water to produce a concrete which when deposited will settle to a flattened mass, but shall not be so wet as to cause a separation of the mortar from the coarse aggregate in handling. Consistency.

IX. REINFORCING.

34. *Reinforcing.*—Concrete pavements twenty (20) feet or more in width shall be reinforced. The cross-sectional area of the reinforcing metal running parallel to the center line of the pavement shall amount to at least 0.038 square inch per foot of pavement width and the cross-sectional area of reinforcing metal, which is perpendicular to the center line of the pavement, shall amount to at least 0.049 square inch per foot of pavement length. Reinforcing.

Reinforcing metal shall not be placed less than two (2) inches from the finished surface of the pavement and otherwise shall be placed as shown on the drawings. The reinforcing metal shall extend to within two (2) inches of all joints, but shall not cross them. Adjacent widths of fabric shall be lapped not less than four (4) inches.

X. PLACING CONCRETE.

35. *Placing.*—Immediately prior to placing the concrete, the sub-grade shall be brought to an even surface. The surface of the sub-grade shall be thoroughly wet when the concrete is placed. Placing Concrete.

After mixing, the concrete shall be deposited rapidly in successive batches upon the sub-grade, prepared as hereinbefore specified. The concrete shall be deposited to the required depth and for the entire width of the pavement, in a continuous operation, between transverse joints, without the use of intermediate forms or bulkheads.

In case of a breakdown, concrete shall be mixed by hand to complete the section or an intermediate transverse joint placed as hereinbefore specified at the point of stopping work. Any

concrete in excess of that needed to complete a section at the stopping of work shall not be used in the work.

36. *Finishing.*—The surface of the concrete shall be struck off by means of a template or strike board, which shall be moved longitudinally or crosswise of the pavement. Concrete adjoining the metal protection plates at transverse joints shall be dense in character, and any holes left by removing any device used in installing the metal protection plates shall be immediately filled with concrete.

After being brought to the established grade with the template or strike board, the concrete shall be finished from a suitable bridge, no part of which shall come in contact with the concrete. The concrete shall be finished with a wood float in a manner to thoroughly compact it and produce a surface free from depressions or inequalities of any kind. The finished surface of the pavement shall not vary more than one-quarter ($\frac{1}{4}$) inch from the true shape.

XI. PROTECTION

Protection.

37. *Curing and Protection.*—Excepting as hereinafter specified, the surface of the pavement shall be sprayed with water as soon as the concrete is sufficiently hardened to prevent pitting, and shall be kept wet until an earth covering is placed. As soon as it can be done without damaging the concrete, the surface of the pavement shall be covered with not less than two (2) inches of earth or other material which will afford equally as good protection, which cover shall be kept moist for at least ten (10) days. When deemed necessary or advisable by the engineer, freshly laid concrete shall be protected by a canvas covering until the earth covering can be placed.

Under the most favorable conditions for hardening in hot weather the pavement shall be closed to traffic for a least fourteen (14) days, and in cool weather for an additional time, to be determined by the engineer.

If at the time the pavement is laid or during the period of curing the temperature during the daytime drops below 50 degrees Fahrenheit, sprinkling and covering of the pavement shall be omitted at the direction of the engineer.

The contractor shall erect and maintain suitable barriers to

protect the concrete from traffic and any part of the pavement damaged from traffic or other causes, occurring prior to its official acceptance, shall be repaired or replaced by the contractor at his expense, in a manner satisfactory to the engineer. Before the pavement is thrown open to traffic the covering shall be removed and disposed of as directed by the engineer.

38. *Temperature Below 35 Degrees Fahrenheit.*—Concrete freezing shall not be mixed or deposited when the temperature is below freezing. **Freezing.**

If at any time during the progress of the work the temperature is, or in the opinion of the engineer will, within twenty-four (24) hours drop to 35 degrees Fahrenheit, the water and aggregates shall be heated, and precautions taken to protect the work from freezing for at least ten (10) days. In no case shall concrete be deposited upon a frozen sub-grade.

XII. SHOULDERS.

39. *Construction.*—When shoulders are required, they shall be built upon the properly prepared sub-grade, as shown on the cross-sectional drawing, Fig. 1. The work shall be done to the entire satisfaction of the engineer. **Shoulders.**

STANDARD SPECIFICATIONS FOR TWO COURSE CONCRETE STREET PAVEMENT.

I. Materials.

Cement.

1. The *cement* shall meet the requirements of the Standard Specifications for Portland Cement, adopted by the American Society for Testing Materials, August 16, 1909, with all subsequent amendments and additions thereto, adopted by said Society and adopted by this Institute (Standard No. 1).

When the cement is not inspected at the place of manufacture it shall be stored a sufficient length of time to permit of inspecting and testing. The engineer shall be notified of the receipt of each shipment of cement.

Aggregate.

2. *Fine aggregate* shall consist of sand or screenings from clean, hard, durable, crushed rock or gravel consisting of quartzite grains or other equally hard material graded from fine to coarse, with the coarse particles predominating and passing, when dry, a screen, having $\frac{1}{4}$-inch openings. It shall be clean, hard, free from dust, loam, vegetable, or other deleterious matter. Not more than twenty (20) per cent shall pass a sieve having fifty (50) meshes per linear inch, and not more than five (5) per cent shall pass a sieve having one hundred (100) meshes per linear inch.

Fine aggregate containing more than three (3) per cent of clay or loam shall be washed before using.

Fine aggregate shall be of such quality that the mortar composed of one (1) part Portland cement and three (3) parts fine aggregate by weight, when made into briquettes, shall show a tensile strength at least equal to the strength of 1 to 3 mortar of the same consistency made with the same cement and Standard Ottawa sand.

In no case shall fine aggregate containing frost or lumps of frozen material be used.

3. *Coarse aggregate* shall consist of clean, hard, durable, crushed rock or gravel, graded in size, free from dust, loam, vegetable or other deleterious matter and shall contain no soft, flat or elongated particles. The size of the coarse aggregate shall be such as to pass a one and one-half ($1\frac{1}{2}$) inch round opening and be retained on a screen having one-quarter ($\frac{1}{4}$) inch openings. In no case shall coarse aggregate containing frost or lumps of frozen material be used.

4. *Aggregate for the wearing course* shall consist of a mixture of two (2) parts of the materials specified under *Fine Aggregate*, and three (3) parts of clean, hard, durable, crushed rock or gravel, free from dust, soft particles, loam, vegetable or other deleterious matter, and passing when dry a screen having one-half ($\frac{1}{2}$) inch openings and retained on a screen having one-quarter ($\frac{1}{4}$) inch openings. In no case shall aggregate for wearing course containing frost or lumps of frozen material be used.

5. *Natural mixed aggregate* shall not be used as it comes from deposits, but shall be screened and used as specified.

6. *Water* shall be clean, free from oil, acid, alkali or vegetable matter.

7. *Reinforcement.*—Concrete pavements twenty (20) feet or more in width shall be reinforced with metal fabric. All reinforcement shall be free from excessive rust, scale, paint or coatings of any character which will tend to destroy the bond. All reinforcement shall develop an ultimate tensile strength of not less than 70,000 pounds per square inch and bend 180 deg. around one diameter and straighten without fracture. **Reinforcement.**

8. *Joint Filler* shall consist of prepared felt or similar material of approved quality having a thickness of not less than $\frac{1}{8}$ nor more than $\frac{1}{4}$ in. **Joint Filler.**

9. *Joint Protection Plates.*—Soft steel plates for the protection of the edges of the concrete at transverse joints shall be not less than $2\frac{1}{2}$ in. in depth and not less than $\frac{1}{8}$ in. at any point nor more than $\frac{1}{4}$ in. in average thickness. The plates shall be of such form as to provide for rigid anchorage to the concrete. The type and method of installation of joint protection plates shall be approved by the engineer. **Joint Protection Plates.**

Shoulders. 10. *Shoulders.*—Materials for the construction of shoulders shall be approved by the engineer.

II. GRADING.

Defined. 11. *Defined.*—The term "grading" shall include all cuts, fills, approaches and all earth moving for whatever purpose where such work is an essential part of or necessary to the prosecution of the contract. When to bring the surface to grade, a fill of one (1) foot or less is required, the area shall be thoroughly grubbed. All soft, spongy or yielding spots and all vegetable or other objectionable matter shall be removed and the space refilled with suitable material.

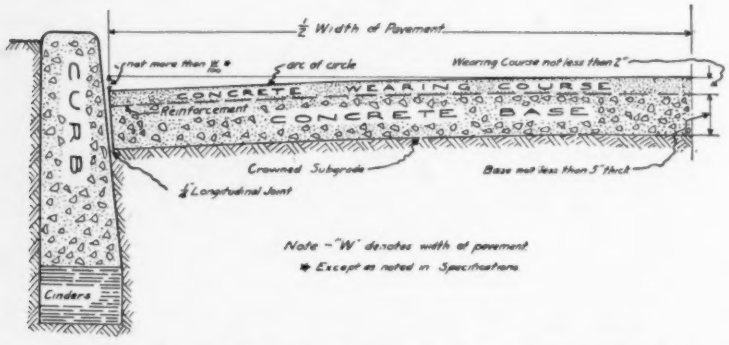

FIG. 1.—TWO COURSE CONCRETE PAVEMENT FOR PAVEMENT OVER 20 FT. WIDE.

Engineer's Stakes. 12. *Stakes* will be set by the engineer for the center line, side of slopes, finished grade and other necessary points properly marked for the cut or fill.

Excess Material. 13. *Excess material* shall be disposed of as directed by the engineer, the free haul not to exceed .....feet.

14. *Over-haul.*—Materials hauled a greater distance than the free haul from the place of excavation shall be paid for at the rate of ..... cents per cubic yard for each additional ..... feet.

Fills. 15. *Fills.*—Embankments shall be formed of earth or other approved materials and shall be constructed in successive layers, the first of which shall extend entirely across from the toe of the slope on one side to the toe of the slope on the other side, and

successive layers shall extend entirely across the embankments from slope to slope. Each layer which shall not exceed one (1) foot in depth, shall be thoroughly rolled with a roller weighing not less than five (5) tons nor more than ten (10) tons before the succeeding layer is placed. The roller shall pass over the entire area of the fill at least twice.

The sides of the embankment shall be kept lower than the center during all stages of the work and the surface maintained in condition for adequate drainage. The use of muck, quicksand, soft clay or spongy material which will not consolidate under the roller is prohibited.

When the material excavated from the cuts is not sufficient to make the fills shown on the plans, the contractor shall furnish the necessary extra material to bring the fills to the proper width and grade. When the earth work is completed, the cross-section of the road shall conform to the cross-sectional drawings and profile shown in Fig. 1.

16. All *slopes* must be properly dressed to a line given by the engineer. **Slopes.**

17. *Finished Grade.*—When the grade line is approached the final grade stakes will be set, for which sufficient notice must be given to the engineer. **Finished Grade.**

NOTE.—In excavating cuts it is considered advisable when the line of the sub-grade is approached, to compact the remaining material by rolling. The depth of material left in the cut to be compressed to the finished grade by rolling will depend upon the character of the material.

III. DRAINAGE.

18. *Drainage.*—The contractor shall construct tile or other drains as shown in the drawings attached hereto. Tile to be laid in the trench at least ..... (.....) inches wide and ..... (.....) feet deep below the top of the adjacent curb. Such trench shall be back filled with crushed stone or pit run gravel with sand removed, which after light tamping shall be ..... (.....) inches in depth. **Drainage.**

19. *Catch Basins.*—All catch basins and manhole tops and all covers of openings of any kind shall be readjusted to the grade by the contractor at his expense.

IV. SUB-GRADE.

Sub-Grade.

20. *Construction.*—The bottom of the excavation or the top of the fill when completed shall be known as the sub-grade and shall be at all places true to the elevation as shown on the plans attached hereto.

The street shall be graded from curb to curb to the proper sub-grade to permit of the specified thickness of paving materials being laid to bring the finished surface of the pavement to the lines and grades as shown on the plans. The sub-grade shall be brought to a firm, unyielding surface by rolling the entire area with a self-propelled roller weighing not less than ten (10) tons, and all portions of the surface of the sub-grade which are inaccessible to the roller shall be thoroughly tamped with a hand tamp weighing not less than fifty (50) pounds, the face of which shall not exceed 100 square inches in area. All soft, spongy or yielding spots and all vegetable or other objectionable matter shall be entirely removed and the space refilled with suitable material.

Where considered necessary, or of assistance in producing a compact solid surface, the sub-grade, before being rolled, shall be well sprinkled with water.

When the concrete pavement is to be constructed over an old roadbed composed of gravel or macadam, and the concrete is to be wider than the old gravel or macadam road, the latter shall be entirely loosened and the material spread for the full width of the roadbed and rolled. All interstices shall be filled with fine material, and rolled to make a dense, tight surface of the roadbed.

21. *Acceptance.*—No concrete shall be deposited upon the sub-grade until it is checked and accepted by the engineer.

22. *Completion.*—Upon the sub-grade thus formed shall be laid the concrete pavement as shown in Fig. 1.

V. FORMS.

Forms.

23. *Materials.*—The forms when required shall be free from warp, of sufficient strength to resist springing out of shape, and shall be equal in width to the thickness of the pavement at the edges. Wooden forms shall be of not less than two (2) inch stock and shall be capped with two (2) inch angle iron.

24. *Setting.*—The forms shall be well staked or otherwise held

to the established line and grades, and the upper edges shall conform to the established grade of the street.

25. *Treatment.*—All mortar and dirt shall be removed from the forms that have been previously used.

VI. PAVEMENT SECTION.

Pavement Sections.

26. *Width, Thickness of Concrete and Crown.*—The concrete pavement shall be ..... (.....) feet wide from face to face of curb. The base of the concrete pavement shall be ..... (.....) inches in depth at the center and ..... (.....) inches in depth at the sides. The wearing course shall be of ..... (.....) inches uniform thickness. The finished surface shall conform to the arc of a circle, as shown in Fig. 1.

NOTE.—The minimum thickness of the concrete base shall be not less than five (5) inches and the minimum thickness of the wearing course shall be not less than two (2) inches. When pavements twenty (20) feet or less in width are to be built on approximately level ground and a flat sub-grade is to be used, sufficient fall for drainage at the sides of the pavement along the curb shall be provided by giving the roadbed the same grade as that proposed for the gutter. The crown of all pavements shall not be more than one-one-hundredth (1/100) of the width except, when deemed advisable by the engineer, the crown of a pavement built on a crowned sub-grade may be increased to one-fiftieth (1/50) of the width to provide sufficient fall for drainage along the sides of the pavement at the curb.

VII. JOINTS.

Joints.

27. *Width and Location.*—Transverse joints shall be not less than one-quarter ($\frac{1}{4}$) inch nor more than three-eighths ($\frac{3}{8}$) inch in width, and shall be placed across the pavement perpendicular to the center line, not more than thirty-five (35) feet part. A longitudinal joint, not less than one-quarter ($\frac{1}{4}$) inch wide shall be constructed between the curb and the pavement. All joints shall extend through the entire thickness of the pavement and shall be perpendicular to its surface.

28. *Protection of Joints.*—The concrete at transverse joints shall be protected with soft steel joint protection plates which shall be rigidly anchored to the concrete. The installation of the metal protection plates shall meet with the approval of the

engineer. The surface edges of the metal plates shall conform to the finished surface of the concrete, as shown in Fig. 1.

All joints over one-quarter ($\frac{1}{4}$) inch high or one-half ($\frac{1}{2}$) inch low shall be removed.

29. *Joint Filler.*—All joints shall be formed by inserting during construction and leaving in place the required thickness of joint filler which shall extend through the entire thickness of the pavement.

VIII. MEASURING MATERIALS AND MIXING CONCRETE.

Measuring Materials.

30. *Measuring.*—The method of measuring the materials for the concrete, including water, shall be one which will insure separate and uniform proportions of each of the materials at all times. A bag of Portland cement (94 lbs. net) shall be considered one (1) cubic foot.

Mixing.

31. *Mixing.*—The materials shall be mixed to the desired consistency in a batch mixer of approved type, and mixing shall continue for at least forty-five (45) seconds after all materials are in the drum. The drum shall be completely emptied before mixing successive batches. The drum of the mixer used shall revolve at a speed not less than the minimum nor more than the maximum number of revolutions shown in the following table:

Rated Capacity, cu. ft. Unmixed Material.	Capacity, Bags of Cement in 1 : 2 : 3 mix.	Revolutions per Minute of Drum.	
		Min.	Max.
7 to 11	1	15	21
12 to 17	2	12	20
18 to 23	3	12	20
24 to 29	4	11	17
30 to 33	5	10	15

Retempering.

32. *Retempering* of mortar or concrete which has partially hardened, that is, mixing with additional materials or water, shall not be permitted.

Consistency.

33. *Consistency.*—The materials shall be mixed with sufficient water to produce a concrete which when deposited will settle to a flattened mass, but shall not be so wet as to cause a separation of the mortar from the coarse aggregate in handling.

Cement. Required.

34. *Cement Required.*—A cubic yard of concrete base in place shall contain at least 1.4 barrels of cement and a cubic yard of wearing course in place shall contain at least 2.97 barrels of cement.

The engineer shall compare the calculated amount of cement required according to these specifications and plans attached hereto with the amounts actually used in each section of concrete between successive transverse joints, as determined by actual count of the number of bags of cement used in each section. If the amount of cement used in any three adjacent sections (between transverse joints) is less by two per cent, or if the amount of cement used in any one section is less by five per cent than the amount hereinbefore specified, the contractor agrees to remove all such sections and to rebuild the same according to these specifications, at his expense.

IX. REINFORCING.

34. *Reinforcing.*—Concrete pavements twenty (20) feet or more in width shall be reinforced. The cross-sectional area of the reinforcing metal running parallel to the center line of the pavement shall amount to at least 0.038 square inch per foot of pavement width and the cross-sectional area of reinforcing metal, which is perpendicular to the center line of the pavement, shall amount to at least 0.049 square inch per foot of pavement length. Reinforcing.

Reinforcing metal shall be placed between base and wearing course and shall not be less than two (2) inches from the finished surface of the pavement and otherwise shall be placed as shown on the drawings. The reinforcing metal shall extend to within two (2) inches of all joints, but shall not cross them. Adjacent widths of fabric shall be lapped not less than four (4) inches.

X. PROPORTIONING AND PLACING CONCRETE.

A. CONCRETE FOR BASE.

36. *Proportions.*—The concrete shall be mixed in the proportions of one (1) bag of Portland cement to not more than two and a half ($2\frac{1}{2}$) cubic feet of fine aggregate, and not more than four (4) cubic feet of coarse aggregate, and in no case shall the volume of the fine aggregate be less than one-half ($\frac{1}{2}$) the volume of the coarse aggregate. Concrete for Base.

35. *Placing.*—Immediately prior to placing the concrete, the sub-grade shall be brought to an even surface. The surface of the sub-grade shall be thoroughly wet when the concrete is placed.

After mixing, the concrete shall be deposited rapidly in successive batches upon the sub-grade prepared as hereinbefore specified. The concrete shall be deposited to the required depth and for the entire width of the pavement, in a continuous operation, between transverse joints, without the use of intermediate forms or bulkheads.

The concrete shall be brought to a comparatively even surface, the thickness of the wearing course below the established grade of the pavement. Workmen shall not be allowed to walk on the freshly laid concrete and if sand or dust collects on the base it shall be removed before the wearing course is applied. The reinforcing metal shall be placed upon and slightly pressed into the concrete base immediately after it is placed.

In case of a breakdown, concrete shall be mixed by hand to complete the section or an intermediate transverse joint placed, as hereinbefore specified, at the point of stopping work. Any concrete in excess of that needed to complete a section at the stopping of work shall not be used in the work.

B. CONCRETE FOR WEARING COURSE.

Concrete for Wearing Course.

38. *Proportions.*—The mortar for the wearing course shall be mixed in the manner hereinbefore specified in the proportion of one (1) bag of Portland cement and not more than two (2) cubic feet of "Aggregate for Wearing Course" hereinbefore specified.

39. *Placing.*—The wearing course shall be placed immediately after mixing and in no case shall more than forty-five (45) minutes elapse between the time that the concrete for the base has been mixed and the time the wearing course is placed.

40. *Finishing.*—The wearing course shall be struck off by means of a template or strike board, which shall be moved longitudinally or crosswise of the pavement. Concrete adjoining the metal protection plates at transverse joints shall be dense in character and any holes left by removing any device used in installing the metal protection plates shall be immediately filled with a mortar composed of one (1) part Portland cement to not more than two (2) parts of fine aggregate.

After being brought to an established grade with the template or strike board, the concrete shall be finished from a suitable

bridge, no part of which shall come in contact with the concrete. The concrete shall be finished with a wood float in a manner to thoroughly compact it, and produce a surface free from depressions or inequalities of any kind. The finished surface of the pavement shall not vary more than one-quarter ($\frac{1}{4}$) inch from the true shape.

XI. PROTECTION.

Protection.

41. *Curing and Protection.*—Excepting as hereinafter specified, the surface of the pavement shall be sprayed with water as soon as the concrete is sufficiently hardened to prevent pitting, and shall be kept wet until an earth covering is placed. As soon as it can be done without damaging the concrete, the surface of the pavement shall be covered with not less than two (2) inches of earth or other material which will afford equally as good protection, which cover shall be kept moist for at least ten (10) days. When deemed necessary or advisable by the engineer freshly laid concrete shall be protected by a canvas covering until the earth covering can be placed.

If at the time the pavement is laid, or during the period of curing, the temperature during the daytime drops below 50 degrees Fahrenheit, sprinkling and covering of the pavement shall be omitted at the direction of the engineer.

Under the most favorable conditions for hardening in hot weather, the pavement shall be closed to traffic for at least fourteen (14) days, and in cool weather for an additional time to be determined by the engineer.

The contractor shall erect and maintain suitable barriers to protect the concrete from traffic, and any part of the pavement damaged from traffic or other causes occurring prior to its official acceptance, shall be repaired or replaced by the contractor, at his expense, in a manner satisfactory to the engineer. Before the pavement is thrown open to traffic the covering shall be removed and disposed of as directed by the engineer.

42. *Temperature Below 35 Degrees Fahrenheit.*—If at any time during the progress of the work the temperature is, or in the opinion of the engineer will within twenty-four (24) hours drop to 35 degrees Fahrenheit, the water and aggregates shall be heated and precautions taken to protect the work from freezing for at

least ten (10) days. In no case shall concrete be deposited upon a frozen sub-grade.

XII. SHOULDERS.

Shoulders. 43. *Construction.*—When shoulders are required, they shall be built upon the properly prepared sub-grade, as shown on the cross-sectional drawing, Fig. 1. The work shall be done to the entire satisfaction of the engineer.

DISCUSSION.

Mr. E. S. Larned.—It is a matter of considerable moment whether the contractor shall find a place of deposit or whether it shall be provided by the municipality. It seems to me that if there is excess material that the city should at least provide a place for depositing it and not compel the contractor to buy an area on which to place waste material. Mr. Larned.

Mr. Percy H. Wilson.—Mr. President, that is something controlled by local conditions. If the excess material is disposed of as directed by the engineer, it may be either at a place that he selects or that selected by the contractor. Mr. Wilson.

Mr. H. J. Kuelling.—I do not believe we ought to limit ourselves to the "roller." The specifications should read "roller or tractor." We do not own a roller, and I think a "tractor," or any heavy rolling vehicle is satisfactory. Mr. Kuelling.

Mr. Larned.—There should be some more specific reference to the type of roller than is made. If you are consolidating an earth fill, it makes considerable difference whether you use a ten-ton roller on three wheels or a tandem roller; the width of tire also affects the results considerably. A grooved roller is a good thing. In consolidating embankments for the double purpose of preventing settlement and having them watertight, it is common practice to use a grooved roller; it would be desirable to specify it should be a three-wheeled roller,—the rear wheels doing the work. Mr. Larned.

Under the specifications the contractor would have good reason to expect that he would be allowed to make a fill not over one foot in depth, and I can see soil conditions where perhaps you might want to limit the layer to not over six inches or perhaps not over four inches; there should be some little latitude given.

The specifications also would lead the contractor to believe that he must furnish the extra material to bring the sub-grade to the proper width and elevation, not only at the expense of

Mr. Larned. excavating and hauling, but perhaps purchasing the material. The community should provide borrow pits where the contractor can obtain this material, and not require him to speculate on that feature.

Mr. Boynton. MR. BOYNTON.—Mr. President, it would seem to me that no matter whether the pits are to be provided by the community or the contractor, this condition is taken care of in advance. The contractor's original figure is influenced by this provision, but not the ultimate cost of the work, since in the end the community pays the cost, directly or indirectly.

Mr. Kuelling. MR. KUELLING.—Our plans more frequently show where open ditches are not needed than where they are needed. The specifications should read, "Open ditches shall be constructed along the concrete road except as shown on the drawings." I do not think it is the practice among the highway departments, at least in the middle west, to show the location of the ditches on the side of the road, except where there is something special in the way of tiling, etc.

Mr. Boynton. MR. BOYNTON.—In the central west where we are dealing with more or less flat country, probably Mr. Kuelling's suggestion is in order; but I do not believe it is good practice for us to write it in a specification which we hope will be put into universal use. In the more mountainous parts of our country it is absolutely necessary to show the layout of ditches, and I think that the same thing may be assumed in Illinois, Iowa, Wisconsin and Indiana. Personally, I would like to see the paragraph remain unchanged; it is as good for Pennsylvania, as it is for Iowa.

Mr. Parry. MR. O. R. PARRY.—In our city and some state work on roadways there are a good many fills of tin cans, etc., that are soft. I think that the specifications should require fills that they be hard.

The President. PRESIDENT HUMPHREY.—Why not prohibit "perishable and other objectionable matter?" Is that agreed to?

Mr. Boynton. MR. BOYNTON.—Yes.

Mr. Kuelling. MR. KUELLING.—Mr. President, I do not believe it is always possible to store material on the job. I would like to know what the committee means by the phrase "on the job." It is not possible to store cement along a country road.

PRESIDENT HUMPHREY.—Why not omit "on the job," as Mr. Kuelling suggests? "Shall be stored a sufficient length of time." The President.

MR. BOYNTON.—That can be done. Mr. Boynton.

MR. PARRY.—Mr. President, I think it would be a good thing to provide that cement shall not be over a certain age. I have met a very great deal of trouble in country districts with cement, which we did not know how long it had been stored in the warehouse, and which would not set up; I have had this experience three or four times in the last year and a half. It would be a wise provision if we could have some clause there, for country work particularly, and generally for all kinds of work, so they could not give you very stale cement. Mr. Parry.

PRESIDENT HUMPHREY.—It seems to me, Mr. Parry, that the standard specifications of the American Society for Testing Materials provides against cement that has lumps or is caked. It is immaterial how long cement is stored, it might be stored five hundred years, so long as it does not absorb moisture it does not cake, and as long as it would harden properly, it would be all right; if it caked or even hardened to any extent, it would not meet the standard specifications. The President.

The Chair would inquire as to the word "quartzitic;" "quartzite" would be a better word.

MR. WILSON.—The difference of opinion in the committee between "quartzitic" and "quartizite" was that "quartizite" definitely stated what the material should be, while "quartizitic" meant that it should be of equal hardness to but not necessarily "quartizite." Mr. Wilson.

MR. O. P. CHAMBERLAIN.—Mr. President, I question somewhat the advisability, as a practical proposition, of testing all sand with a screen to determine the fineness. And I would also like to ask the committee on what grounds the provision as to the amount of fine material is based. Now one reason for raising that question is, that if it were introduced in the city specifications on special assessment work it would, in my opinion, leave the way open for a good many contests on the assessments. Mr. Chamberlain.

MR. BOYNTON.—This was really a compromise among the members of the committee, but I believe we are unanimous in believing that the coarser particles should predominate. Mr. Boynton.

Mr. Chamberlain. MR. CHAMBERLAIN.—It is my opinion, and I may be wrong, that that provision if lived up to would cut out 90 per cent of the material coming into Chicago. We have some of the very best sand of any district.

Mr. Larned. MR. LARNED.—I want to read to you this specification for sand, which I think is a good one; "The sand for the construction of the road shall be most carefully selected. Samples of sand shall be submitted to the Highway Commissioner sufficient time in advance of starting the work that adequate tests may be made. All sand shall be washed, free from loam, extremely fine particles, vegetable matter or deleterious material. The sand shall be properly graded and not more than 5 per cent shall pass a sieve having 100 meshes per lineal inch. Fine aggregate shall be of such quality that the mortar composed of one part Portland cement and three parts fine aggregate by weight, when made into briquettes will show a tensile strength at least equal to the strength of 1 to 3 mortar of the same consistency made with the same cement and standard Ottawa sand."

I think the limitation of 15 per cent through a 50-mesh sieve is arbitrary, and it would be very difficult to justify it. It might reflect the opinion of an engineer, but you might find one hundred engineers that would differ with him. It would within my knowledge exclude a great deal of perfectly satisfactory sand, and just adds a difficulty in the way of concrete construction.

Mr. Chamberlain. MR. CHAMBERLAIN.—I agree with what Mr. Boynton has said, that an excess of dust is objectionable. I think that what Mr. Larned has said is about in line with the principal point that I make, that really you are proposing a specification that is almost impossible to live up to. As a matter of fact, it won't be lived up to if you make it. There is another very bad feature which I mentioned, but did not go into detail; in special assessment work in Chicago, if property holders can prove that the specifications have not been followed, they can make a great deal of trouble and might prevent the contractor from receiving the money for doing the work. I also think that 2 per cent is a good deal lower than is necessary; 5 or 7 per cent would be more in line with what would be perfectly good practice.

The President. PRESIDENT HUMPHREY.—Would you raise that to 15 per cent?

Mr. Chamberlain. MR. CHAMBERLAIN.—I would eliminate that entirely.

MR. J. L. MINER.—Doesn't it make a great deal of difference as to the character of this fine material? Some fine material is an advantage because of the added strength and greater density of the concrete. I know of an instance where 20 per cent of the cement was replaced with extremely fine limestone dust, and the strength of the concrete was increased. It seems to me that if we limit the percentage of this fine material, we should define what it is, or in some way eliminate the injurious fine material. Mr. Miner.

MR. WILSON.—Mr. President, I think we all agree that we can eliminate the 5 per cent of fine material, and as one of the committee, I am heartily in favor of doing that. But there is one other big factor which we have not been able to cover in the specifications, and that is a test to determine the abrasive qualities of the fine material. We do know that limestone dust does increase the compressive strength of concrete, but we believe that in a concrete road, because of objectionable qualities, it should never be used. In revising the specifications we have eliminated the use of limestone dust entirely. One of the reasons for putting in the 15 per cent was that we would be able to get a better grade of aggregate, an aggregate graded from fine to coarse. There should be some requirement at a middle point, somewhere between the fine and coarse aggregates. Mr. Wilson.

MR. CHAMBERLAIN.—I am glad this matter of limestone screenings has been brought up. I do not know on what ground Mr. Wilson makes his statement that limestone screenings in a road is not suitable. I know in sidewalk work and in some driveway work that I have seen, it has been used and as far as I know, it is entirely satisfactory. I think it would be well for Mr. Wilson to give us an example of some road that he knows of in which limestone screenings has been a failure. I can show him a good many places where it has been a success. My own driveway at home was built with limestone screenings about six years ago, and it is just as good as the day it was put in. There is a driveway for heavy teaming near the Artesian Stone Company. There is a driveway that has been used by the Brownell Meal Company, put in six or seven years, that has been a success. I do not know of any driveway that has failed. And that is the reason I am asking this question, where does the information Mr. Chamberlain.

Mr. Chamberlain. come from that limestone screenings does not make a satisfactory road. I can show three or four pavements where it has been entirely satisfactory.

Mr. Larned. MR. LARNED.—In the specification written if you leave quartzitic stone it eliminates the limestone.

Mr. Wig. MR. WIG.—We have hard limestone and soft limestone, and I do not see any objection to using hard limestone screenings. We have made a great many tests, showing that limestone screenings will not only give high abrasive values, but appear to have high compressive values; and I think that it is objectionable, to eliminate any material without knowing more about it. I would suggest changing this paragraph by raising 15 to 20 and 2 to 5.

Mr. Boynton. MR. BOYNTON.—I do not want to see limestone or limestone screenings discriminated against, if we are sure they will make a good road; but I do think we want to eliminate excessively fine material of any character, whether it is clay or limestone dust. I am sure Mr. Chamberlain would gladly agree to 4 or 5 per cent substituted for the 2, so far as the test is concerned. But I do not think we ought to be led astray by such results as Mr. Miner refers to.

The President. PRESIDENT HUMPHREY.—The Chair would like to suggest, as far as the question of hard and soft is concerned, that has already been taken care of, as Mr. Larned points out, by the word "quartzitic." But the requirement under consideration limits the amount of fine material, regardless of whether it is hard or soft.

Mr. Miner. MR. MINER.—I do not advocate an addition of 20 per cent of limestone. I just cited that experience as an example; it was in construction work in which there would be no abrasion on the material. My point was, shall we eliminate all fine material or shall we make a difference between different fine materials? The limestone dust I referred to was not screenings; it was the dust blown out in crushing crystallized limestone to make sand. There was no sand on the work, and this dust was mixed in the concrete; tests of this mixture made of very large sized pieces of concrete in the field, gave higher strength than the concrete which did not contain the dust. We ought to make a difference between different fine materials, as some of them possibly may give greater density and greater wearing quality to the concrete.

The Convention adopted the following: "Not more than 5 per cent shall pass through a sieve having 100 meshes per lineal inch." Mr. Miner.

MR. WIG.—Referring to the hardness it says, "quartzitic grains or other equally hard material." It ought to be "approximately as hard;" because if you say equally as hard it would eliminate some granites. Mr. Wig.

MR. BOYNTON.—The Committee accepts that amendment. Mr. Boynton.

MR. LARNED.—I can see good reason for eliminating the percentage of material passing the 50 mesh sieve. If that is cut out entirely it may, as Mr. Wig remarks, promote the use of sands in certain localities that perhaps will be extremely fine. But what are you going to do where localities furnish no other sand? This country is not blessed with uniformly good material, and if sand is found it will be used under this specification. Mr. Larned.

PRESIDENT HUMPHREY.—These specifications are drawn for the purpose of representing as near as possible average conditions that are generally obtainable. It is to be conceived that there are localities where these specifications would not meet the local conditions,—in that case, the local engineer, or whoever is in charge, must modify the specifications to suit such conditions. The specifications should secure an average sand of a good quality. The President.

MR. E. D. BOYER.—To make this more or less elastic, to fit the varying conditions, why not change it to read from 15 to 20 per cent and from 5 to 7 per cent? They have different materials in Florida, Wisconsin and California, and you want your specifications elastic enough to fit those different localities. Mr. Boyer.

PRESIDENT HUMPHREY.—It would be better to give a single minimum requirement; make it whatever seems reasonable, and the engineer can modify it to meet local conditions. The President.

MR. W. W. DEBERARD.—If you plat the mechanical analysis of the sand on the logarithmic curve you usually get a straight line. In ordinary sand you will find that they have removed with the gravel, considerable material less than $\frac{1}{4}$ in. In a particular case that came to my attention, they had to put back some of this material in order to get a satisfactory sand. You ought to have three points on your curve to define the material accurately. Mr. DeBerard.

The Convention adopted the following: "Not more than

Mr. DeBerard. 20 per cent shall pass a sieve having 50 meshes per lineal inch and not more than 2 per cent shall pass a sieve having 100 meshes to the lineal inch."

Mr. Chamberlain. MR. CHAMBERLAIN.—Could not the large size aggregate be raised without any objection to $1\frac{3}{4}$ or possibly to 2 in.?

Mr. Miner. MR. MINER.—Is that a square opening or a round opening?

Mr. Chamberlain. MR. CHAMBERLAIN.—All the screening that I know of, both of gravel, sand and crushed stone, is done through a circular opening. That is, they are circular when they start; they don't always stay circular. All plants of any size have rotary screens. It might be well to change the specification to read $1\frac{1}{2}$ in. diameter.

Mr. Boynton. MR. BOYNTON.—If it is preferable we can specify more carefully the size of the screens—personally, I never liked the idea of passing a stone through a ring—but the Committee understood that we were dealing with a punched screen in wording that paragraph; if it is necessary we will make it clearer. I want to ask Mr. Chamberlain if $1\frac{1}{2}$-in. stone is a commercial product.

Mr. Chamberlain. MR. CHAMBERLAIN.—Insert the word "diameter" after "inch"; that will make it clear—"$1\frac{1}{2}$ in. diameter opening."

One and a half can be made a commercial product. The usual commercial sizes in this locality for crushed stone are 2 in. and $1\frac{1}{4}$ in. It is simply a matter of fixing your screen. In this district the selection of the screens is largely in the hands of the commissioners of the City of Chicago; there will be variations of $\frac{1}{8}$ in.

Mr. Boynton. MR. BOYNTON.—I think it advisable to develop some discussion as to the maximum size of aggregate. It seems to me that a particle larger than $1\frac{1}{2}$ in. in diameter would not work well; I should like to have Mr. Kuelling and others who have been doing this work, discuss that question.

Mr. Kuelling. MR. KUELLING.—My experience has been that we order $1\frac{1}{2}$ inch, and actually get $1\frac{1}{4}$-inch stone. The screen is rotated and a large percentage of the inch and a half will never go through the screen at all. I have reduced the size in practice, for the reason that if you use too large stone you get too large faces exposed in the surface of the road, and if it is an exceedingly hard stone there is danger that it will be struck and kicked out; whereas with the inch and a half size we do not seem to have that trouble.

MR. STUBBS.—With reference to the natural mixed aggregate, I wish to say that in Texas I got more than 600 carloads from one deposit last year; I had an engineer at the pit testing the gravel, and the variation was less than 1½ per cent. Mr. Stubbs.

MR. BOYNTON.—If the specification does not prohibit the use of bank run gravel, the committee has made a mistake. We want it understood that the use of bank run gravel is dangerous as a whole and if the paragraph could be made any stronger we would gladly have reworded it. There are too many roads of concrete which have failed because of the use of bank run gravel. Mr. Kuelling told you this morning his experience in 1912 with bank run gravel. I doubt if he will ever use it again. The chances are that in 90 per cent of the cases you will find that the bank run carried an excessive amount of sand; another bad feature is its lack of uniformity in the same deposit; every wagon or carload will vary in the amount of sand and its relation to the coarser aggregate. I think it is wrong to allow its use. Mr. Boynton.

MR. LARNED.—I would like to emphasize that I cannot see any reason for using bank run gravel except economy; and in the majority of instances it has been found to be anything but economical. You can use more gravel and you won't overload your mortar with sand, if you separate the sand and gravel and use the correct proportions. Mr. Larned.

MR. WIG.—I would like to ask the committee how they set the limits of .038 per sq. in. per foot of pavement width, and also the .049. Also I would like to suggest in the latter part of the second paragraph, "Where the pavement is placed over a swamp or bog, reinforcing metal shall be placed in the center of the pavement," if this was ever done the reinforcing material could probably never carry over 1,000 to 1,500 lb.; I have not figured it, but off-hand it seems to me that it could not possibly carry over 1,000 to 1,500 lb. in tension before you would rupture the concrete on the under side. So it is almost useless to place the reinforcing in the center of the slab. It should be at either the top or bottom, and if conditions are very bad, it should be both at the top and bottom. Mr. Wig.

Reinforcing metal, to take care of changes due to temperature or moisture, should be placed not less than 2 in., nor more than 3 in. below the finished surface of the pavement—in the

Mr. Wig. case of moisture or temperature change, the restraint is all at the bottom. The stress in the concrete would be maximum at the point of restraint, therefore, it would be at the bottom, and the reinforcement should be just as close to the bottom as possible. I would suggest, therefore, Mr. President, that this be changed to read, "Concrete pavements 25 ft. or more in width shall be reinforced with wire fabric. When the sub-grade is suitable the reinforcing metal shall be placed as shown on the drawings"; eliminate the balance and let the engineer apply it.

Mr. Wilson. MR. WILSON.—Mr. Wig, do you believe that it is proper to place reinforcement closer to either the top or bottom of a pavement than 2 in.?

Mr. Wig. MR. WIG.—In our sea water exposure tests we found metal embedded an inch from the surface of good concrete was well protected from corrosion. Therefore, I think it could be placed as closely as an inch from the bottom of the slab.

Mr. Wilson. MR. WILSON.—How would you place the wire fabric one inch from the bottom of the slab where the aggregate was $1\frac{1}{2}$ in.?

Mr. Wig. MR. WIG.—Where wire fabric of large mess was used in heavy reinforcement, and stone aggregate was specified as large as an inch and a half, they would fall through the wire cloth.

Mr. Wilson. MR. WILSON.—They would fall through providing the wire cloth did not rest on those stones. If it did, it would be $1\frac{1}{2}$ in. from the bottom.

Mr. Wig. MR. WIG.—Theoretically, the wire should be as near the top as possible. It may be impractical to place it closer than $1\frac{1}{2}$ or 2 in. in many cases. If the wire were in place, the concrete would have to work itself around the wire, otherwise the wire would have to be worked into place by displacing the stones.

Mr. Boyer. MR. BOYER.—I haven't heard the committee reply to Mr. Wig's question regarding how they arrive at the area of metal to be used.

Mr. Boynton. MR. BOYNTON.—The amount of metal was assumed to be sufficient to take care of temperature stresses. When the roadway is considered as a slab over a bog, the reinforcement is, of course, being used in an entirely different way and possibly in a case of that kind we have not given it sufficient consideration.

Mr. Pease. MR. B. S. PEASE.—Mr. President, it was not my desire to say anything on this subject until after I had had an opportunity

of presenting my paper. However, I will answer the question as to the methods used in arriving at the particular sectional area of steel specified by saying that actual results obtained by the use of certain weights of reinforcement show that it is not advisable to use a lighter reinforcement than the one suggested. These sectional areas of steel correspond to that furnished by a particular material that has so far proven to be satisfactory. Mr. Pease.

There is one point on which I must disagree with Mr. Wig, and that is about placing the metal in the middle of the slab. I cannot agree with that as I believe the reinforcement should be either in the top or the bottom, depending upon the conditions.

I also wish to call your attention to another point in the specifications. The first part of the second paragraph states, "When the sub-grade is unstable, the reinforcing metal shall be placed as shown on drawings." It is certain that a swamp or bog referred to later would be considered as an unstable sub-grade and what would apply to one in a general way would apply to the other. I believe that in cases where you are constructing pavements over a foundation that we will say is a swamp or bog, the reinforcement should be in the bottom.

I also do not believe it necessary to lap your mesh 4 in. along the sides of the sheets, 2 in. being ample. With a lap of 2 in. you will have a stronger construction at the joint than at the middle of the sheet, in other words, for a crack to form along the lap it would be necessary to actually rupture the concrete by a shearing action, and for that reason I believe 2 in. is ample in order to get sufficient strength at the joint.

I wish to also call your attention to another point in the specifications that refers to coatings; I personally believe that a plain material is preferable to one that is galvanized. However, as this may possibly limit competition it would not be advisable at this time to include galvanizing as an objectionable coating.

PRESIDENT HUMPHREY.—You refer to the last sentence from the end, do you not, which says, "All reinforcement shall be free from excessive rust, scale, paint or coatings of any character"? The President.

MR. PEASE.—Yes. Mr. Pease.

PRESIDENT HUMPHREY.—There is an omission, and that should read, "of any character which would tend to reduce or destroy the bond." The President.

Mr. Boynton. MR. BOYNTON.—That is omitted.

Mr. Wilson. MR. WILSON.—A concrete road over 20 ft. wide if built on a bog or marsh should be reinforced both top and bottom. The Committee advocates a minimum thickness of slab of 6 in., and the reinforcement if placed $2\frac{1}{2}$ in. from the bottom and $2\frac{1}{2}$ in. from the top, the two layers are located practically in the center of the slab; if two sheets are used, twice the amount of reinforcement is placed that is necessary, which was the reason for recommending its location in the center.

Mr. Boynton. MR. BOYNTON.—We should not lose sight of the fact that although we build a pavement to last forever, it is going to wear, and we do not want the reinforcement so near the surface that before the pavement has possibly completed its usefulness, the reinforcement is going to be exposed. If we put our reinforcement within an inch of the top, as soon as the inch is gone, the road is of no further use. There is still 5 in. of good concrete. I believe that if we could lay a slab with the reinforcing within an inch of the top and an inch of the bottom we would have a stronger slab, but the reinforcing would be more quickly exposed and the life of the road greatly lessened.

Mr. Larned. MR. LARNED.—I was interested to know to what extent this specification limits the use of reinforcement. Is there any reason why the transverse reinforcement should not be just as strong as the longitudinal? How close are the main members to be and of what section, and are the transverse wires to be of the same diameter as the longitudinal wires? What is this wire fabric; is it woven, welded, or soldered wire? Does it exclude fabricated metal of perhaps a different manufacture?

Mr. Boynton. MR. BOYNTON.—These quantities were selected because they covered fabric considered the most suitable, produced by the manufacturers marketing such material. The limits are placed so that all come within it, a number of different manufacturers.

Mr. Larned. MR. LARNED.—Some engineers have a very different opinion in regard to the transverse, the diagonal wire, depending on how they are introduced into the fabric. Mr. J. R. Worcester of Boston gives no value to the woven diagonal wire. His value of reinforcement is based entirely upon the main member.

Mr. Boynton. MR. BOYNTON.—The specifications give the value in both directions, and apply whether woven diagonal wire or wire woven at right angles is used.

PRESIDENT HUMPHREY.—I suggest that the committee consider the question of changing this requirement. It is out of place to discuss the placing and location of reinforcement under materials, and it really ought to be under reinforcing. The President.

MR. KUELLING.—Is it the intention to place reinforcement throughout the entire width of the pavement? I certainly do not think it is necessary to reinforce the entire width. Mr. Kuelling.

MR. BOYNTON.—The committee shall be pleased to consider the matter of changing the requirements as President Humphrey suggests, but personally I am opposed to cutting out as much of the paragraph as Mr. Wig suggests. In reference to Mr. Kuelling's remarks about reinforcing the full width of the pavement, will say that I know of instances where only the middle 20 ft., say, were reinforced and cracks occurred as a result just at the edge of the reinforcement; seeming to indicate that where a pavement is to be reinforced, the fabric should be carried across the entire area. Mr. Boynton.

PRESIDENT HUMPHREY.—It is true on boggy land. The President.

MR. BOYNTON.—I believe that the reinforcement should be carried across entire area, whether the land is boggy or not. A sudden change from reinforced slab to plain concrete is always sure to create a crack in the pavement. Mr. Boynton.

MR. WIG.—I suggest that the committee insert under reinforcement two paragraphs, "Concrete pavements 20 ft. or more in width shall be reinforced with wire fabric" and "when the sub-grade is unstable the reinforcing metal shall be placed as shown on drawings, which would leave the decision with the engineer as at present." Mr. Wig.

MR. BOYNTON.—I believe the sentence, "when the subgrade is unstable, the reinforcing metal shall be placed as shown on drawing" will take the place of the one reading, "where the pavement is placed over a swamp or bog, reinforcing metal shall be placed in the center of the pavement." I am opposed, however, to eliminating the rest of the paragraph, since this subject should be covered in one way or another. If our quantities are wrong and the amount of metal we advocate is wrong, we want to correct, not eliminate it. Mr. Boynton.

MR. WILSON.—In preparing this specification we have tried to play safe, and to provide against failures. While we do not Mr. Wilson.

Mr. Wilson. know all about reinforcing concrete roads, and may be willing to change these specifications in another year, we do know that this method insures safety and has a tremendous influence on the decreasing of cracks.

Mr. Wig. MR. WIG.—Concerning what Mr. Wilson says about the success in using reinforcement, I would like to point out that while we have many places in which the cracks have opened up very little and have had success, we do not know that it is due to reinforcement. I know of plain slabs 66 ft. in width, without reinforcement, that are in good condition. Therefore, simply because we have slabs with reinforcement that are in good condition is no reason for recommending reinforcement. I think instead of playing safe, the committee is playing very unsafe, and believe they should eliminate the figures.

Mr. Wilson. MR. WILSON.—Mr. Wig states that we do not know that we are playing safe. An examination of concrete pavements in many parts of the United States, shows that the percentage of cracks in those that are reinforced is less than in those which are not reinforced. It seems absurd to insert a requirement for reinforcement unless we fix some limit as to where and how the reinforcement shall be placed. This committee is composed of a number of highway engineers, and they have been very insistent on making this specification specific, so that the entire judgment shall not be left to them—that they will have at least an indication of the limits to which they may allow a contractor to go in doing this sort of work. I shall be very much disappointed to see those limits entirely taken away and this matter left to the engineers.

Mr. Boynton. MR. BOYNTON.—I believe we owe something to the people who are building concrete roads in the way of recommendations for reinforcement; for us to come together and say that we cannot even suggest something which will be safe, based on past experience, is ridiculous. For authority we have much better proof than documents; we can cite a number of instances where reinforcement has prevented cracks. There are many men building concrete roads today who have not had much experience, and what they really want is the experience of others; why cannot we give them the best available. Possibly our recommendations are not the best, but it has been proved that reinforcing is

good practice. I am sure the convention does not wish to go on record as favoring the building of all widths of concrete pavement without reinforcement. Mr. Larned.

MR. WIG.—There ought to be a statement inserted to caution the use of 35 ft. lengths in dry localities, as we find from Mr. Fletcher's experience in California, the length of slab should be less than 35 ft. in these districts. Mr. Wig.

MR. BOYNTON.—I desire to call attention to the fact that "not more than 35 ft. apart" would not confine anyone to 35 ft. Mr. Boynton.

MR. SMITH.—We have had very good success placing joints every 25 ft. in 21 miles of pavement. I doubt very much whether a slab 50 ft. long would not crack. Mr. Smith.

MR. WILSON.—Mr. Wig, did Mr. Fletcher put joints in his road at all? Is he not covering it with bitumen and sand? Mr. Wilson.

MR. WIG.—The pavements have no joints. He intended to cover them, but there are stretches that have been uncovered since last spring, and I understand he does not intend to cover them. Mr. Wig.

MR. CONNELLY.—This committee should endeavor to minimize the cost of construction. In our territory we could go 50 ft. without danger of a single crack. The less joints, the better pavement you have. Joints increase the cost. I speak of my experience; I had something to do with writing specifications, and I have been an inspector for years. Mr. Connelly.

MR. BOYNTON.—You undoubtedly realize that there is a good deal of evidence to justify us in specifying joints farther apart than last year, which was 25 ft. If we could build a pavement with joints only at the end of the work, this condition would be ideal; if not, we want to get them as far apart as possible, but I believe 35 ft. is the maximum. There is nothing to prevent, however, a closer spacing provided the engineer or municipality wishes them. Closer spacing, of course, will largely be prevented by increased cost. In a matter of this kind we should not leave the specification to be filled out by the engineer but should specify definitely at least the maximum spacing. Mr. Boynton.

MR. LARNED.—I am perfectly willing to accept 35 ft. intervals for joints under average conditions as the maximum. There may be some conditions where the engineer will require additional joints. He might require, furthermore, a contraction joint Mr. Larned.

Mr. Larned. where the road goes from fill to cut; and I think he should. I think the specifications should provide for that.

Mr. Kuelling. MR. KUELLING.—I would like to ask if the committee considered building a curb as part of the pavement without any joint between the curb and the pavement.

Mr. Boynton. MR. BOYNTON.—Mr. President, it was discussed, we believe it can be done and in some instances would be good practice, but it is not covered in the specifications.

Mr. Kuelling. MR. KUELLING.—A great deal of coarse aggregate that we have tested very often contains only 40 per cent of voids. Why can we not use a 1 : 2 : 4 mixture with an aggregate of that kind. I believe we should hold to proportion of 1 : 2 : $3\frac{1}{2}$, but use a leaner mix where the percentage of voids justify.

Mr. Larned. MR. LARNED.—The proportions used should be determined as much by handling the concrete as by anything else. A 1 : 2 : 4 concrete, if the coarse aggregate is well graded, under certain conditions would be a very good working concrete, under others it might prove unsuitable. You must have a little excess mortar to care for the abuse from the mixer to the place of deposit.

Mr. Kuelling. MR. KUELLING.—I brought up this morning the matter of beveling and wish to make it clear that I do not favor beveling off the edge of the pavement, wasting 4 to 6 in. of the width of the pavement.

Mr. Larned. MR. LARNED.—One reason for beveling is the almost certain damage to an automobile tire if there is any dropping away from the slab to the shoulder. We do not want to introduce a danger. If the wheel collapses or a tire be ripped off, even at a moderate speed, it may cause injury. Now, I will agree that we do not want to limit the width of the pavement unnecessarily, but I think a small bevel is a good thing. Furthermore, it will protect the concrete against spalling to a very large extent, and that is an advantage to the slab.

Mr. Kuelling. MR. KUELLING.—I have made it a practice in some of my last work to finish with just a slightly rounded edge of about $\frac{1}{2}$ in. That I have no objection to. But the custom has been to bevel it with a shovel or something of that kind and cut in 2 or 3 in. on the slab.

Mr. Larned. MR. LARNED.—Mr. President, there is one more change I would suggest, the specifications state that, "If at the time the

pavement is laid, or during the period of curing the temperature, during the daytime, drops below 50 degrees Fahrenheit, sprinkling and covering the pavement shall be omitted at the direction of the engineer." Would it not be better to say at the discretion of the engineer? Personally I do not believe that the sprinkling should be omitted with a drop in temperature below 50 degrees Fahrenheit. There is a difference between 50 degrees and 35. It might go down to 35 or even down to freezing at night. Your evaporation is perhaps greater in that range of temperature than it would be at a higher temperature. The air may be considerably drier and I should favor sprinkling. Mr. Larned.

MR. WIG.—The pavement may be left uncovered if the temperature is low, but considerable evaporation may occur at 50 degrees Fahrenheit and it would be on the safe side to lower this to 40 degrees Fahrenheit. Contraction occurring during the first few days is undoubtedly the most serious as the concrete is weakest at this time. Mr. Wig.

MR. BOYNTON.—We have provided that the pavement be covered for protection from frost; now we have covered the formation of frost as well as temperature below 50 degrees. If that is not favored, I should say eliminate everything in this paragraph, because there is so little difference between 40 and 35 degrees. Mr. Boynton.

MR. WIG.—Is this specification intended to take care of pavements in alleys? Very often they are made dished; that is, the top of the pavement is made dished. Mr. Wig.

MR. BOYNTON.—Such was not the intention; no reference is made to alleys. In the note we tried to take care of the various conditions met with in obtaining drainage. For instance, in Chicago, and other cities and towns where drainage is obtained by changing the grade of the gutter, keeping the top of the curb constant, it is necessary to change the cross-section, making the pavement similar to a warped surface; all these conditions, I believe, are covered in the note. Mr. Boynton.

MR. LARNED.—Mr. President, nothing has appeared in the specifications as to how the work is to be measured or paid for. Now, some engineers are paying for their pavement by the square yard and others by the cubic yard of concrete measured in place. Mr. Larned.

PRESIDENT HUMPHREY.—Our standard methods for the measurement for concrete work are on the square yard basis. The President.

Mr. Boynton. MR. BOYNTON.—I suggest we incorporate in this specification some reference to that; make it on the square yard basis rather than on the cubic yard basis.

Mr. Larned. MR. LARNED.—Just one reason for putting it on the cubic yard basis. A great many contractors can figure it better and certainly more rapidly on the cubic yard than on the square yard basis. I know one active city department that is measuring concrete road slabs on the cubic yard basis; I was not quite prepared to approve of it at the start, but the more I thought it over the better I liked this basis. I think, further, that the specifications should contain a summarized list of items upon which the contractor bids.

The President. PRESIDENT HUMPHREY.—It seems to me that that would be a part of the proposal and form contract and would not necessarily be in the specifications. It may be desirable to have this committee report a form of proposal and contract covering the suggestions that you have made.

Mr. Wig. MR. WIG.—I am not opposed to the use of reinforcement, but I think it is poor logic to suggest that the reinforcement be placed in the most convenient place without respect to its efficiency. The fact that it has always been placed in a given manner does not of itself warrant the continuance of this practice. I would like to suggest the following: "Reinforcing metal shall be placed where the sub-grade is of old macadam or to distribute the effect of expansion and contraction due to temperature changes and moisture content," eliminating part of the sentence reading "not less than 2 in. nor more than 3 in. below the finished surface of the pavement."

The President. PRESIDENT HUMPHREY.—I would suggest that you might combine those two to read, "Reinforcing metal may be used where the sub-grade is unstable, or of old macadam, or to distribute the effect of expansion and contraction due to changes in temperature and moisture content."

Mr. Boynton. MR. BOYNTON.—I understand then that according to Mr. Wig, we will not suggest the position of the reinforcement, leaving that to the engineer.

Mr. Wig. MR. WIG.—The committee can state in a note its opinion with regard to the location, but this should not go in the specification.

MR. BOYNTON.—I wish to emphasize the point that cracks are reduced in concrete pavements through the use of a small amount of reinforcement. Simply because we cannot figure this out to a nicety and specify every theory we use in connection with reinforcement, is no reason we cannot make a recommendation. I do not object particularly to eliminating this paragraph from the specifications and substituting a foot note, but it does seem to me that we should make a more definite suggestion for the benefit of the engineer who has never built a concrete pavement and has not had an opportunity of investigating them. Mr. Boynton.

MR. H. S. DOYLE.—The object of putting reinforcement in a concrete pavement is to prevent objectionable cracks. Those objectionable cracks must necessarily be in the surface of the pavement; if they are in the bottom they are not objectionable. It is only objectionable cracks that we are trying to prevent, and if we put the reinforcement in the bottom we are not going to prevent objectionable cracks in the top. Therefore, I think that the reinforcement should be near the top surface. Mr. Doyle.

MR. BOYNTON.—I object strongly to striking out the amount of reinforcement. We know from experience that the amount of reinforcement as specified has accomplished the result we are after; possibly a little more would be better. For the benefit of those who are not able to attend these meetings, but must depend upon our experience, the responsibility devolves upon us to make certain and definite recommendations which will indicate the best practice today. Whether or not the reinforcement is placed in the bottom or the top is not of much moment, and I would say strike out "three inches" and say that the reinforcement shall be not less than 2 in. from the top; this guards against the possibility of the reinforcement occurring too near the surface. Mr. Boynton.

PRESIDENT HUMPHREY.—These specifications, all specifications are tentative. They are changed and modified as it is found desirable. We all admit that it is desirable to use reinforcement. We will agree that this amount recommended will do no harm. It may be found to be insufficient or it may be all right. There should be some amount given in the specifications. The President.

MR. BOYNTON.—It would seem to me to say not less than that amount; a man can use twice or four times that and still Mr. Boynton.

Mr. Boynton. be within the spirit of the specifications. We do not wish to leave the amount of the reinforcement to the judgment of the engineer who has had no experience in concrete paving. I would like to suggest as a modification of Mr. Wig's motion, that we eliminate the position of the reinforcement and leave the amount.

Mr. Kinney. MR. KINNEY.—I want to protest against the elimination of the whole clause on location of reinforcement. We must limit the location to not less than 2 in. from the top surface in order to prevent careless placing and subsequent exposure of the reinforcement.

REPORT OF COMMITTEE ON REINFORCED CONCRETE HIGHWAY BRIDGES AND CULVERTS.

It has seemed best to the Committee to cover certain points in specifications for Reinforced Concrete Highway Bridges and Culverts by definite specifications, but certain other points must be varied according to the special circumstances of the case and, therefore, what is considered to be the best engineering practice is stated and recommended for adoption by the public. If any of the other national associations, of recognized standing, take up the same work, it would seem well to co-operate with them. It has been the policy of the Committee to adopt the standard specifications or recommended practice of any national society whose authority was generally admitted.

The following specifications and recommendations are submitted to the Institute, not as final, nor even as voicing the unanimous opinion of the members of the Committee, but merely as preliminary suggestions, in the hope of bringing out the discussion of doubtful points and information regarding questions which the Committee could not answer. Any information or criticism will be thankfully received and carefully considered.

Specifications.

1. The specifications for *Reinforcement* and *Cement* should conform to those of the Institute.

2. The specifications for *Aggregates* should conform to those of this Institute.

3. The *Unit Stresses* in reinforced concrete, and reinforcement, should conform to the recommended practice of the Institute.

Recommended Practice.

DEAD LOADS.

4. The following are given as average weights per cu. ft. of the materials mentioned, but if the weights of the materials to be actually used are definitely known to be different from those given, the correct weights should be used.

Materials.	Lbs. per Cu. Ft.
Earth filling	110
Plain concrete	150
Reinforced concrete	155
Steel	490
Cast iron	450
Vitrified brick	140
Common brick	125
Granite and limestone masonry	165
Sandstone	160
Macadam-Telford	150
Pine, fir, etc	42
Oak and yellow pine	48
Creosoted	60

5. The weight imposed by *earth filling* should, in ordinary cases, be considered as including all filling included between vertical planes passing through the faces of the abutments.

If, however, the height of the fill exceeds about two-thirds the distance face to face of the abutments, the live load may be neglected and a very considerable proportion of the weight of the filling considered will be supported by friction between it and the approach filling. The amount of load thus transmitted is greatly affected by the cohesion of the soil, of which there is nearly always more or less.*

This whole subject requires further investigation.

LIVE LOADS.

Class A Bridges.—Main thoroughfares leading from large towns.

6. In view of the extensive introduction of the *heavy motor trucks and traction engines*, and the probable general use of such vehicles in the future, it is recommended that bridges on main thoroughfares and other roads which are likely to be used for heavy hauling, be designed to carry 20-ton trucks, with axles about 10 ft. c. to c., 14 tons on rear axle and 6 tons on fore axle; wheels about 5 ft. c. to c. Outside of the large cities it is recommended that only one such vehicle be assumed to be on the bridge at any one time, the likelihood of more than one being on the bridge, in a position to produce maximum stresses at the same time, is so

* This paragraph is not approved by Mr. Lemuel Holmes nor by Mr. Henry H. Quimby.

remote that this assumption is considered safe. It is advised that such very heavy loads be considered as occupying only the ordinary width of the road, about 8 ft. in width and about 35 ft. in length. Congested traffic of heavily loaded wagons or motor trucks will rarely impose a load of more than 100 lb. per sq. ft., over a considerable area. The above mentioned 20-ton truck gives a load of about 140 lb. per sq. ft., on the area actually occupied, but it is considered extravagant to assume that a large bridge is covered with such heavy loads. 100 lb. per sq. ft. is thought ample to assume for the loading of spans more than 60 ft. long, in designing the trusses or main girders. It is thought to be safe to reduce this assumed load in the case of longer spans, to the following amounts:

Length of Span, ft.	Assumed Load, lbs. per sq. ft.
80	90
100	80
125	75
200 and over	70

With all intermediate spans in proportion.

7. *Sidewalk Loads.*—The greatest load that is liable to be imposed on a bridge sidewalk, occurs when there is some excitement in the neighborhood, which attracts a large crowd, and for which the bridge affords an especially good point of view. In that case the crowd forms a compact mass, against the railing, not more than 4 ft. deep, making a load seldom exceeding 100 lb. per sq. ft., over a very considerable space. The remaining portion of the sidewalk may be covered by a moving crowd which can scarcely weigh more than 40 lb. per sq. ft. It may be advisable, sometimes, to so design sidewalk slabs, that if a street car or motor truck accidently gets upon the sidewalk, it will not go through. Such accidents are so rare, that it is thought safe to allow materials to be stressed somewhat beyond the elastic limit in such cases.

8. *Class "B" Bridges.*—Although it is impossible to determine beforehand, especially in the newer parts of the country, whether any given road is to be used for heavy traffic, it seems extravagant, at least in the cases of larger spans, to design bridges to carry much heavier loads than can be expected to come upon them. It is recommended that bridges of this class be designed to carry 15-ton trucks, with axles 10 ft. apart, 5 tons on the front and

10 tons on the rear axle. This will allow for a considerable overloading of existing motor trucks. It is further recommended, that only one truck be assumed to be on the bridge at one time, in designing the floor system, that it be assumed to cover a width of 8 ft. and a length of 35 ft. and that the remainder of the bridge is covered with a load of about 90 lb. per sq. ft., for spans up to 60 ft.

9. The longer spans, the trusses and main girders should be designed for the following loads:

Length of Span, ft.	Assumed Load lbs. per sq. ft.
80	80
100	70
125	65
150	60
200 and over	55

With intermediate spans in proportion.

10. *Sidewalks.*—Sidewalks should be designed to carry the same loads as in the case of Class "A" Bridges.

Special Bridges.

11. City bridges and bridges carrying traffic connected with mines, quarries, lumber regions, mills, manufactories, etc., require special consideration and should, of course, be designed to carry any load which can reasonably be expected to pass over them, bearing in mind the likelihood of heavy traction engines and motor trucks coming into extensive use in the not distant future.

Stringer Loading.

12. The maximum stress in a stringer, due to a wheel load, occurs evidently when the wheel is directly over it. It is not thought proper to assume any distribution of the load to adjacent stringers, unless the bottom reinforcement in the slab is made continuous. In that case the distribution is proportional to the relative stiffness of the slab and the stringers, said stiffnesses being proportional to the moments of inertia, multiplied by the modulus of elasticity of materials and inversely proportional to the cube of the span. In determining this distribution, due account must be taken of the fact that deflection of the slab

decreases toward the end of the stringers, and also of the fact, that whatever load is carried to the adjacent stringers, deflects them also. It is therefore recommended that wherever practicable the bottom reinforcement of slabs be made continuous over the stringers.

Slab Loading.

13. The distribution in a direction parallel to the supports of a concentrated load resting on a slab, supported at two opposite edges only, evidently depends upon the same principles as those mentioned under *Stringer Loading*. The main difference being that what corresponds to the stringer in the former case is of indefinite width in the present case. Adequate theoretical investigations of this question appear to be lacking. Some excellent experimental work has been done but not of sufficient extent to really prove much. Your Committee hopes to make a more complete report on this subject later. For the present it seems fair to assume that the distribution each side of a concentrated load is equal to about one-third the length of the span, and that the cross reinforcement should be designed accordingly, which would require it to have an area of at least one-half of the principal reinforcement. The distribution of a concentrated load through earth filling on the top of a slab, does not appear to be very well understood, the Committee has not, thus far, been able to find any records of adequate theoretical or experimental investigation of the subject. It is hoped to obtain more data later.

Bridges Carrying Electric Cars.

14. Electric traction is still in its infancy and nobody is able to forecast its future development. It seems probable, however, that it will not be profitable to run cars weighing more than 50 tons each, at a speed that would be permitted on any public road. If very high speeds are desired, the traction company will doubtless be required to operate over its own right-of-way. It is recommended that bridges carrying either urban or inter-urban electric cars be designed to carry 50-ton cars on two trucks, spaced 30 ft. c. to c., each truck having two axles spaced 7 ft. c. to c. The Committee sees no reason for changing the customary practice of assuming that an axle load is distributed over 3 ties.

Loading on Arches.

15. The deflection of an arch being much less than that of a beam of the same length, the method recommended for determining the lateral distribution of a concentrated load over arch sheeting appears to be different from the distribution over flat slabs. It seems doubtful if the distribution in each direction can be greater than twice the thickness of the arch sheeting. This question should be investigated.

Stresses in Arches.

16. As all arches that are not provided with hinges, act as elastic arches until cracks are formed, due to excessive tension at some point or points in the concrete, it is manifestly proper to calculate the stresses in them according to the elastic theory.

17. As concrete is a very poor conductor of heat, it is not thought necessary in calculating reinforced concrete arches, to assume so much variation in temperature as is usual in designing steel structures, although the outside layers of concrete are of nearly the same temperature as the surrounding air, and those layers are stressed more heavily than any of the others, it is thought that an extreme variation of about 80 deg. in the Northern States is sufficient to allow for, in any case, and that can be reduced if the arch ring is thicker or if there is much earth filling in the spandrels.

BEARING POWER OF PILES.

18. The usual formula for the safe bearing power of wooden piles is:

$$B=\frac{2WH}{S+1}$$

in which, W = Weight of hammer in pounds,
H = Height of fall of hammer in feet,
S = Penetration in inches per blow, average of last few blows.

19. If reinforced concrete piles are molded before being driven, the head of the pile is usually cushioned more or less, and the pile is generally much heavier in proportion to the weight of the hammer than is the case with wooden piles. It is recommended that the hammer should be at least as heavy as the pile.

20. If concrete piles are molded in place, measures should be taken to prevent damage to them by the driving of neighboring piles or otherwise.

21. The Committee hopes to make some further investigations in the subject before submitting a final report.

BEARING POWER OF SOILS.

22. This subject is under an investigation by a committee from the American Society of Civil Engineers. It may be some years before their final report is submitted and even that will be subject to revision from time to time, as human knowledge is extended. In the meantime the Committee would submit the following preliminary table:—

Material	Safe Bearing Power, tons per sq. ft.
Quicksands and wet soils	0.1 to 1.0
Dry earth, according to depth below surface	1 to 3
Moderately dry clay confined	2 to 4
Dry stiff clay	4 to 6
Sand confined	2 to 6
Sand compact and cemented	4 to 8
Gravel cemented	8 to 12
Rock	25 to 200

Foundations should be carried down below frost unless they are on rock and thoroughly drained. Soil that contains the roots of plants is generally compressible. Undisturbed soil is much less compressible than filling or similar soil, even though it has been in place many years. The bearing power of sand, gravel and dry clay increases rapidly with the depth below the surface of the ground. None but the smallest structures should be founded on earth filling.

24. The pressure of earth against abutments, wingwalls and retaining walls varies so widely with the character and condition of the earth in question, that nothing more than a few general suggestions can be given. It is hoped that the Committee from the Society of Civil Engineers, which is studying the bearing power of soils, will take up this subject also. In ordinary cases where the filling is well drained its pressure will seldom be more than that of a liquid weighing 25 lb. per cu. ft., and is frequently much less.

The pressure due to land slides is often several times this amount. If the filling is clayey and is allowed to become waterlogged, its lateral pressure is greatly increased. The effect of the freezing of the filling must also be considered.

REQUIRED WATERWAY.

25. The usual formula for waterway for culverts is:

$a = C\sqrt[4]{A^3}$,

in which,

a = Required area of culvert in sq. ft.

A = Drainage area in acres,

C = A constant, depending on the length and character of the drainage area and may vary from about .3 to 2.0 in regions where the mean annual rainfall is about 50 in.

The capacity of the culvert will be much greater if the wing-walls are flush with the abutments and flare about 30 deg., the sides and bottom of the culvert are smooth and straight, and the bottom has a good slope.

If reliable information covering a number of years can be obtained regarding the adequacy of the old bridge crossing the same stream, it is much more useful in determining the size of a culvert or bridge than any formula,

Respectfully submitted by the Committee,

WILLIS WHITED, *Chairman.*
LEMUEL HOLMES.
A. N. JOHNSON.
A. M. LOVIS.
HENRY H. QUIMBY.*

* Mr. Henry H. Quimby offers the following comments on certain portions of this report:

Par. 3. I think that the stresses in both steel rods and concrete allowed in the Standard Building Regulations of the Institute adopted February, 1910, which I presume constitute the "recommended practice" referred to, are rather high for bridge work which is liable to more severe usage and is also subject to drenching with water. We cannot expect as high a value in 1-2-4 concrete as 2000 lbs. even at six months age and under ordinary speed of testing. I am in favor of scaling down the allowable stresses of 500 lbs. on extreme fibre in bending, 400 lbs. in columns, and a ratio of moduli of 20.

Par. 4. I think that it ought not to be necessary to include a table of weights of materials.

Par. 5. I think that all earth filling over a culvert or other bridge exerts its normal pressure because it would not permanently arch itself if the culvert were to be removed. I have inquired and find that it is railroad practice to design on this basis. Also it is railroad practice

to figure live load on the culvert, only assuming that it is distributed, *i. e.*, not figuring for concentrated and eccentric loading.

Par. 8. A 15-ton road roller is liable to be on any county bridge and it may have 11 tons on the rear axle.

Par. 13. Should be rewritten in the light of recent tests and the lateral distribution should be a function of the thickness of slab instead of a proportion of the length of span. The engineering papers—or perhaps the Am. Soc. C. E. Transactions—contained a few months ago a report of tests of distribution of a vertical load through sand. I have searched for it but do not find it. We might recommend 1 horizontal to 2 vertical as current practice.

Par. 15. What recommended method is referred to?

What does "each direction" mean? Longitudinal and transverse or only transverse both ways from the point. In the latter case omit "each direction" and say *four times* the thickness.

Par. 18. If we go into such specifications we ought to cover steam driving as well as drop driving. I think that the Engineering News formula for steam driving is quite too liberal.

Par. 25. Is there not some error in your formula for waterway? For a drainage area of 6000 acres it gives from 1350 to 9000 sq. ft. area of culvert. Talbot's formula gives from 130 to 690 sq. ft. Myers' gives from 77 to 308 sq. ft. Our sewer formula for a district with almost no absorption because of roofs and pavements and where there must be no damming back for a moment gives 2500 sq. ft. A recent bridge built by this City over Frankford Creek at tide water has 350 sq. ft. for each 6000 acres of drainage area, and the Chestnut Street bridge over the Schuylkill River has about 50 sq. ft. for each 6000 acres.

Journals No. 3, 4 and 5 presented herewith complete the issue of Vol. X, 1914.

Journals No. 1, 2, 6 and 7 have been published, and if copies are desired, application should be made to the Free Public Library of Philadelphia which holds our supply of past publications.

Binding charge for Vol. X has in some instances been billed by mistake and payment has been made. In such cases credit will be given to apply on the binding of Vol. XIV.